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Effects of Acid Forming Emissions in Livestock

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EFFECTS OF ACID FORMING
EMISSIONS IN LIVESTOCK

PROCEEDINGS OF AN INTERNATIONAL WORKSHOP
held
November 18 - 19, 1986
in
Edmonton, Alberta, Canada

Edited
by
R.W. Coppock and L.E. Lillie

February 5, 1992

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Foreword

The purpose of this workshop was to discuss and review the published and anecdotal information relevant to the effects of acid forming emissions on livestock health and productivity. The objectives of the workshop were to: (i) discuss what harmful effects of acid forming emissions in livestock are known; (ii) discuss and review anecdotal information on the harmful or potentially harmful effects of acid forming emissions in livestock; (iii) identify the kind and magnitude of research that is necessary to identify potential or existing harmful effects of acid forming emissions in livestock.

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EFFECTS OF ACID FORMING EMISSIONS IN LIVESTOCK
PROCEEDINGS OF AN INTERNATIONAL WORKSHOP

REASON FOR THE WORKSHOP

R. Christian

The Animal Health Division has been involved in investigating potential acid gas emmission problems and their impact on animal health for a long time. In recent years, the Alberta Environmental Centre has been assisting in these investigations.

This workshop has its origins in a request from Dr. M. Kostuch, who is the Chairman of the Public Advisory Board to the Acid Deposition Research Program (ADRP). The request was to the Minister of Environment to consider some of the issues related to animal health with respect to acid gas emission. You will hear more about ADRP today, as some of the research and service work that is on-going in the ADRP will be presented. The ADRP impact and focus is on acid gas effects on humans and on the environment in general.

I would like to review the theme and the purpose of this workshop. First of all, it is important to recognize that this workshop is oriented towards scientific issues and related research questions, and it really is not in any way a political platform. The workshop will focus on the effects of acid emmissions from the oil and gas industry in Alberta on livestock health and productivity. We will review the published and observed effects of acid emmissions on livestock, and establish what scientific data and research is needed to identify the impact of these emmissions.

There are three objectives: (1) to discuss what harmful effects of acid forming emmissions in livestock are known and have been well documented, (2) to discuss livestock producer observed effects of acid emmissions, and (3) to identify the kind and magnitude of additional research and investigation needed to identify harmful effects.

At the end of the workshop I hope that we have more knowledge and ideas for future research. You will of course be aware that funding is necessary for research. We hope to identify possible sources of funds as part of the program tomorrow morning.

I would like to introduce Dr. Len Lillie, Head of the Animal Sciences Wing at the Alberta Environmental Centre, who will further set the stage for the conference. As you may be aware, the Centre now has a new facility for carrying out inhalation toxicology research.

INTRODUCTION

L.E. Lillie

Acid emissions are a fact of life in industrialized societies. ere are generally two kinds of patterns that are seen with this problem. In Alberta, we do not have the kind of acid emission problems that exist in eastern Canada, the eastern United States and in Europe. Our problems are somewhat different. In a general way, acid emissions in this part of the country come from hydrocarbon and sulphur-producing industries. In other parts of the country and in other parts of the world, acid forming emissions come from increased urbanization, and from hydrocarbon-consuming industries. It is also important to keep in mind that with respect to some types of acid emissions, natural emissions are very important. Certainly with respect to the total amount of sulphur compound emitted into the atmosphere; things like geothermal activity, sea spray, and biological decay continue to be significant sources.

There is concern with respect to potential effects on human health and these are being investigated in a variety of ways. Some research programs are focused on the immediate effects and other programs are investigating the chronic effects, for example, the phenomenon of hypersensitivity. Our focus is somewhat different. We are here to look at some of the agricultural concerns and, more especially, problems associated with livestock health.

Environmental effects are also being looked at in other programs. We are all well aware of the sensitivity of aquatic systems to acid emissions and also of the sensitivity of vegetation. These other components of the environment are sensitive in ways that are often more easily measured and observed than those which can be related to animal health or livestock production.

If we take the title of the conference and convert it into a question, the first and overall question that we need to try and resolve is:

> "Do acid forming emissions affect livestock under Alberta conditions"?

In the end, that is the single question that we are here to try and answer. Since this is an audience of mixed academic disciplines and vocations, I thought it would be worthwhile discussing the diagram (Figure 1) I am presenting.

Health and disease (poisoning), whether we are talking about cattle, sea snails, people, or any other kind of living organism, is not a static condition. Living organisms are not simply healthy or diseased. They are always on a spectrum, a dynamic spectrum which is constantly shifting from one side to the other depending on the impacts on that particular organism. In a general way, the three factors which affect the status of health or disease are the causative agent or agents, the resistance of the host or affected animal and the mitigating effects of the animal's environment.

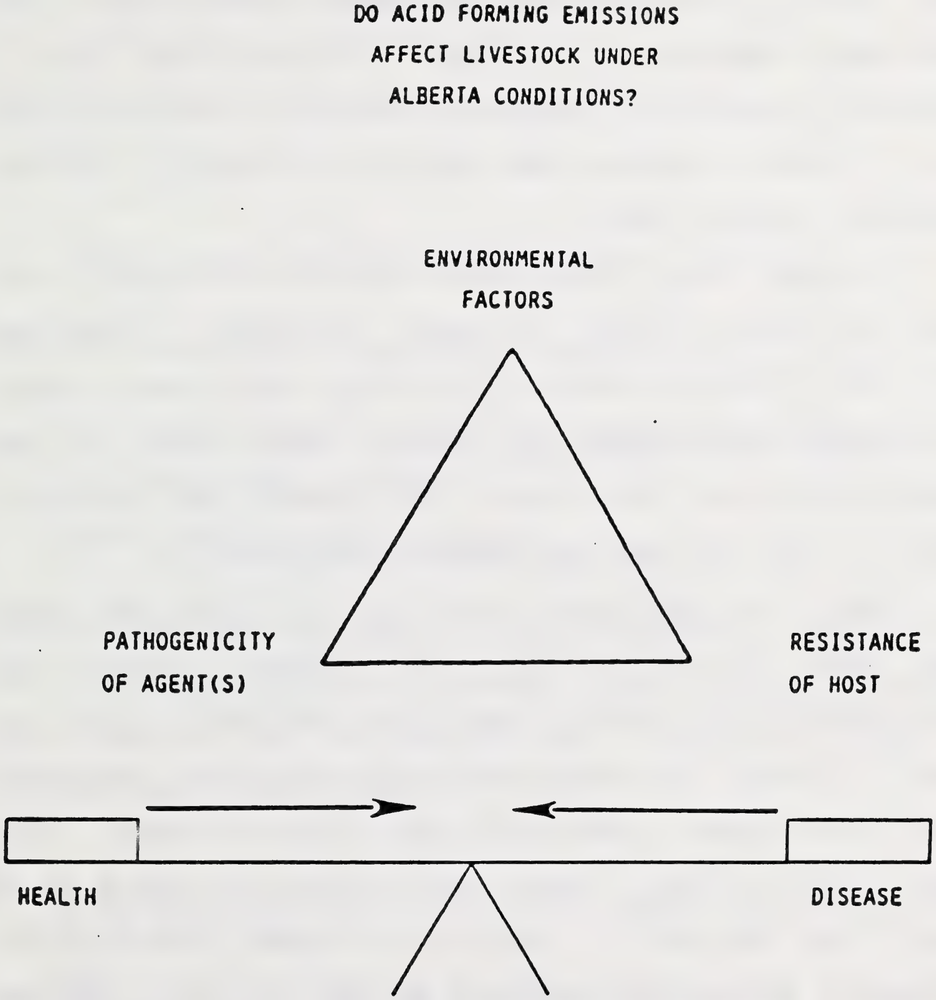

Figure 1 - Triangle depicting the dynamic interactions between the effects of toxic substances, infectious agents, and environmental factors on animal health.

The pathogenicity, or the disease-causing potential of whatever kind of agent we are considering is the first factor in the triad. This may be an infectious agent or a chemical agent or, as is often the case, a combination of a number of different agents acting in concert. Of course, it is much more difficult to sort out or factor out a disease situation when there are a number of different components acting in concert.

The second factor is the intrinsic resistance of the host to that particular agent or group of agents. Resistance is always more difficult to determine when we are talking about chemical agents; particularly when exposure to chemical agents occurs at lower concentrations over long periods of time. However, the resistance of the host is still an important component in the triad.

Finally, the environmental factors are all of the other factors that impact on that particular living organism. In this case, environmental factors might include the way the animal is raised, the way it is housed, vaccination status, nutrition, weather, and whatever other factors impact on the health status of that individual. If all these factors acting in concert tend to move the spectrum to the right, then the animal is going to be diseased. Disease may not necessarily be an overt condition, but can also be a suboptimal condition; that is, we can talk about suboptimal production as being a kind of disease. If the condition moves further over to the right, it becomes an overt condition. And if it gets far enough over, the situation may become terminal for that particular organism. This balance between health and disease is constantly shifting, not only for livestock, but, of course, for all of us.

A variety of questions can be raised, each with varying degrees of difficulty; and the answer to one question can result in additional questions. For example, if we answer the question:

> Do acid forming emissions affect livestock?

Then the next question we should ask ourselves is:

> What are the effects of acid forming emissions on livestock?
>
> Can we define those effects?
>
> Can we quantitate them in some way?

So we progress down this question and answer sequence. And if we look at acid forming emissions as a potential cause of disease, then there are a number of additional questions that we can ask with respect to this particular class of agents.

> Do we have to be able to identify the emissions and quantify them to the extent possible?
>
> "What are the acid forming emissions that are present in livestock producing areas in Alberta?

A lot of this information is already available because we harvest the same kind of information that is being used for public health and industrial monitoring.

What quantity of acid forming emissions are present in Alberta?

First we need to define the chemical composition and quantities of chemicals present. You all recognize that virtually everything is potentially toxic and that toxicity depends on the dose and conditions of exposure. The dose is quantity of toxic substances, generally expressed in terms of body weight; and conditions of exposure are route (inhalation, oral and external) and duration of exposure.

How are these acid forming emissions distributed?

We know that, in Alberta, we do not have a large single point source as, for example, the "super stack" in the Sudbury basin. Rather, we have many small point sources. These are not solely associated with gas plant operations; there are others as well. We have to look at these sources in terms of chronological and geographical distribution.

Do chronology and geography represent the association with disease patterns?

This is especially important since we will be talking about diseases associated with acid forming emissions.

It is another step to move from association to a causal relationship.

What happens to these emissions in the environment?

How are they transported?

How do these emissions change chemically in the environment?

What is their atmospheric chemistry?

What happens to them?

How do they come down?

Where do they come down?

Where do they precipitate?

Where do they deposit?

Distribution, precipitation and deposition all may affect potential exposure to livestock in any particular area.

What are the interactions of these emissions with other components of the environment?

One important interaction is:

How do these emissions interact with soil in terms of release of nutrients?

Disease conditions that are associated with acid forming emissions may not necessarily be direct effects. There may be indirect effects such as the influence of pH, perhaps reduced pH, on the increased mobility of ionic elements in the soil. The interactions between soil, plants and animal nutrition is something that Dr. Smart will discuss. These examples represent indirect toxic effects.

Let's move now from the agent to the subject. Here we will try to answer:

> What clinical disease syndromes (toxicoses) are observed in livestock associated with acid forming emissions?
>
> Exactly what is being observed?
>
> Can we describe it in some kind of consistent way?

These conditions may be observed by livestock producers, nutritionists, agriculturalists and veterinarians. This is what is referred to epidemiologically as anecdotal information. At this workshop, anecdotal is certainly not used in any pejorative way. A collection of anecdotal information is often the first step in trying to define the real world effect. After having identified what kind and what quantity of acid emissions are associated geographically and chronologically with animal toxicoses and other diseases, we can ask:

> What kind of disease patterns or conditions are being seen in the field, and the diagnostic and research laboratories?
>
> Can we tie these two together?
>
> Can we demonstrate a cause and effect relationship?
>
> What do we have to do to identify a cause and effect relationship between acid emissions and disease patterns?
>
> Do we have any toxicoses or other disease conditions that have been verified by experimental reproduction?
>
> Could we prove cause and effect through experimental reproduction of these conditions?
>
> Do similar toxicoses or disease conditions occur elsewhere in the absence of acid forming emissions?

One of the things that we must try to do is determine whether there are causes other than acid emissions which are known or can reasonably be surmised to induce the disease patterns. More than one agent can often induce the same disease pattern. Acid emissions might be synergistic or additive to other agents. Take, for example, the sulphur-selenium question. It is thought that diseases due to selenium deficiency are present in areas that have high sulphur emissions. Some claim there is evidence to establish a cause and effect relationship. However we also know that the same kinds of selenium diseases occur in areas remote from any sources of acid emissions.

> How can we factor agents out and determine which one might be causing which disease component?

The other side of that question is:

> Do similar disease patterns occur in other areas where there are acid emissions?
>
> Do we know of other livestock producing areas where acid emissions occur and where the same disease patterns occur?
>
> Could other causes of disease interact with acid emissions to produce clinical disease (additive or synergistic causes)?

As we mentioned, acid emissions may simply be a component in a very complex causative relationship. Somehow, we need to be able to factor out other causes before we can ascribe cause or blame to acid emissions. Further:

> Can we reproduce the conditions using acid emissions under experimental circumstances?

> Can we reproduce suspected disease conditions using acid forming emissions or using acid forming emissions along with some other causative agent?
>
> Can we eliminate the disease patterns by eliminating the acid emissions?

These are the kinds of tests which are used to demonstrate cause and effect relationships.

If we have been able to ascribe a cause and effect relationship between acid emissions and one or more disease conditions, the final question is:

> What can be done to mitigate the effect of acid emissions under practical circumstances?

These are the questions that will be addressed in the discussion sessions tomorrow. And as a last point, I want to leave you with the appreciation that life is not always as simple or straightforward as it might seem. The purpose of this meeting is to discuss the effects of acid emissions on livestock.

I would like to present you now with a case with at least some documentation to the effect that livestock are a cause of acid emissions. This is not out of some strange obscure journal. This is taken from the prestigous British scientific journal New Scientist, October 23, 1986. The article contains a serious discussion concerning the effects of heavy concentrations of livestock, or more correctly, of livestock emissions (deposits?) on acid precipitation.

A serious theory being developed in Europe, the "Ammonia Theory", concerns the problems they are having with loss of forests and dying trees, not only in Britain but also in Continental Europe and Sweden. This theory suggests that intense concentrations of livestock and the ammonia produced therefrom acts as an activating agent for sulphur emissions in the atmosphere and also as a source of nitric acid.

So if we are going to be developing the thesis here that industrial sources of acid emissions may be affecting livestock we had better remember that the opposite may be true under other circumstances. I do not suggest that this is the case in Alberta; we simply don't have the livestock concentration. However, this is an interesting twist on the acid precipitation question.

AN OVERVIEW OF ALBERTA ENVIRONMENT'S ACID DEPOSITION PROGRAM

Carl L. Primus

INTRODUCTION

Atmospheric emissions of pollutants, their deposition, and potential long-term detrimental effects on the environment have not only become a serious scientific issue, but a focus of significant public concern in Alberta. Nevertheless, industrial development is dictated by economic opportunity and cannot wait for long-term research projects to provide all of the answers to possible problems. In many cases, we must rely on judgment and external experiences to allow promotion of developmental goals without sacrificing critical components of our environment. We are aware that our perspective of the relationship between environmental quality and industrial development is diverse and varies from region to region. However, the concern for environmental quality has never been higher in our history than at present, and determined efforts by the public to have an influential role in the decisions that affect the fate of our environment are rightfully increasing.

With the use of emission abatement strategies, local ground level concentrations have decreased in the vicinity of new stationary sources. However, the potential for a long-term, progressive, subtle impact on the environment remains. A number of issues and concerns have been identified in documents published by Alberta Environment (Appendix I). Relative to Alberta, our knowledge regarding medium and long-range transport of acid rain, and the environmental and human health effects of long-term, low-level emissions, is presently limited. Research and monitoring/surveillance programs need to be expanded and implemented to overcome our knowledge deficiencies. To facilitate this, Alberta Environment established the Departmental Acid Deposition Research Program (ADRP).

DEPARTMENTAL ACID DEPOSITION PROGRAM

Acid-forming emissions, such as oxides of sulphur and nitrogen, can be transported from a few to thousands of kilometers. Because of the dramatic deleterious environmental effects observed at Sudbury, Ontario; Trail, British Columbia; and in the vicinity of many point sources in the United States, it was generally believed that emissions resulted mainly in local environmental impacts. However, scientific studies have demonstrated that transport of these emissions occurs over long distances, such as from the Ohio River Valley through the northeastern United States into eastern Canada, from the United Kingdom into Norway, and from the Ruhr Valley in West Germany into Sweden. Similarly, emissions originating in Alberta are transported to areas downwind of major sources, where ecosystems may be sensitive to acid deposition (Sulphur Gas Emissions in the Boreal Forest: The

West Whitecourt Case Study, 1978; Environmental Sulphur Research in Alberta: A Review, 1980). The present and potential impacts of these emissions are not well understood. Some of the concerns are: (a) acidification of surface waters and the potential consequences for aquatic biota, including fish; (b) acidification of soils and their influence on the total watershed, vegetation and aquatic systems; (c) direct effects on agricultural crops and forest tree species; and (d) direct and indirect effects on human and animal health.

Objectives of the Program

The overall objective of the ADRP is to design, coordinate, and implement a research and monitoring program concerning acid forming emissions and their ecological effects in Alberta. The program will provide scientific information for evaluating and reviewing Alberta's current air quality standards, emission guidelines, and regulatory controls with respect to socio-economic and environmental consequences of atmospheric pollutants in order to satisfy the concerns of Albertans.

Specific objectives of the Departmental program are to:

1. Undertake routine monitoring of air, water, soil, and vegetation to determine short- and long-term trends in environmental quality.
2. Characterize sensitive environmental components and develop methodologies to: (a) identify and/or predict environmental deterioration caused by acid forming substances in Alberta;

and (b) determine when environmental deterioration begins and whether or not the effects are reversible.

3. Characterize, separate, and quantify the contributions of emissions from local sources and from the medium- and long-range pollutant transport toward environmental effects of acidification.
4. Review, coordinate and implement a research program concerning acid forming emissions and their short- and long-term environmental and health effects.
5. Determine the socio-economic impacts of acidification and develop a scientific basis and approach for preventive and/or mitigative strategies and environmental protection.
6. Provide support and integration for research, monitoring, and other activities of the Departmental Committee on Acid Deposition, Alberta Government/Industry Acid Deposition Research Program (ADRP), the Western and Northern Canada LRTAP Technical Committee (W&NC-LRTAP), and other agencies.

Program Components

The Acid Deposition Research Program is comprised of five distinct but integrated components:

1. Alberta Environment's Acid Deposition Effects Research Program.

2. The Alberta Government/Industry Acid Deposition Research Program.
3. Western and Northern Canada LRTAP.
4. Departmental Monitoring Program.
5. Inhalation Toxicology and Animal Health Program.

Each of these components is discussed in the ensuing sections.

Alberta Environment's Acid Deposition Effects Research Program

Although scientists still debate which of several mechanisms may be responsible, forest decline evident in Europe and in eastern North America has been attributed to acid deposition. The public and government of Alberta are concerned as to whether a similar decline will occur in our forests as a result of acid deposition. Alberta Environment Acid Deposition Effects Research Program was developed to assess long-term environmental impacts of industrial developments in the oil sands region of northeastern Alberta on forest and aquatic ecosystems. Research has been coordinated under the auspices of the Alberta Oil Sands Environmental Research Program (AOSERP).

Program Development 1975 to 1985

The initial phase of the program (1975 to 1980) accumulated baseline information required to quantify and characterize existing environmental conditions, primarily dominant soil and vegetation types. This baseline information was to be used to identify ecosystems most likely to be impacted by acid deposition and to assess the impact of industrial development on these ecosystems.

Air quality and meteorological networks were established to collect data on local air mass trajectories and climate. This data was used in the development and verification of an air quality model capable of predicting the ground level concentrations of pollutants based on various meteorological conditions and emission levels. The model was used to delineate areas of maximum sulphur dioxide (SO_2) loading (subject to potential acidification) and long-term environmental damage.

To further address the environmental impact of industrial development, precipitation chemistry monitoring networks were established. The accumulated snowpack and event rainfall were extensively sampled and analyzed to determine: (1) trends in the ionic and particulate concentration of precipitation resulting from industrial emissions; and (2) deposition patterns and spatial variability of wet deposition pollutant loadings.

Although baseline information was collected on the sensitivity of terrestrial and aquatic ecosystems to pollutant deposition, strategies had not been implemented to ensure the interdisciplinary, integrated approach needed to understand the complex interrelationships between atmospheric and biological processes. In a review of the research and monitoring activities undertaken during 1975 to 1980, research deficiencies were identified and future research recommended.

Specific recommendations were:

1. To characterize and quantify regional and local source emissions to ascertain their relative contribution to environmental acidification.
2. To integrate episodic air quality data with receptor response in order to (a) characterize sensitive environmental ecosystems, and (b) develop methodologies to identify and/or predict measurable short- and long-term effects of acidic or acidifying substances on terrestrial and aquatic ecosystems.
3. To develop a scientific basis and approach for preventive strategies and long-term environmental protection-management.
4. To coordinate departmental research on acid deposition with other private and public agencies in Alberta and the rest of western Canada.

From 1980 to 1985, the program concentrated on addressing these research deficiencies, especially characterizing and quantifying the ecological effects of acidic and acidifying substances. Considerable effort and resources were expended to develop a more thorough understanding of the atmosphere-biosphere interface. Research consisted of field and laboratory investigations of plant responses to emitted pollutants. Specific projects were geared to the accurate and frequent measurements of pollutant concentration occurrences, and their interface with physiological, phenological and productivity responses in vegetation species. A second major interface, between soil nutrients, microbiological processes and vegetation was also studied.

With respect to atmospheric research, regional surveys continued to sample and chemically analyze wet deposition. Wet deposition, however, is only one of two major mechanisms in the transfer of pollutants from source to the ecosystem receptor. Air pollutants released into the atmosphere are deposited continuously and cumulatively through both dry and wetfall processes. Methodologies and instrumentation technology for measuring dry deposition to a forest canopy were developed and implemented on an experimental basis. However, more evaluation and research will be required before dry deposition monitoring techniques can be employed on a routine operational basis. In conjunction with these studies, research to determine the transport, dispersion and transformation rates of sulphur and nitrogen oxides emissions were undertaken to facilitate the investigation of the medium- to long-range transport of acid-forming emissions from a major emission source in the oil sands area.

A summary report for research and monitoring work carried out in the oil sands area between 1975 to 1985 is in preparation.

In the 10-year period 1975 to 1985, research clearly demonstrated the high degree of natural variability in ecosystem parameters, especially in forest ecosystems, which make it difficult to detect subtle changes in the ecosystem occurring as a result of low acid-forming emission levels. Therefore, it became clear that a new strategy was required for evaluation of acid deposition effects in the oil sands area.

The New Five-Year Research Plan

Effects research can only be done meaningfully in the oil sands area using long-term monitoring techniques in which biological variability is statistically accounted for. Before embarking on any additional new research efforts in the northern forested areas, Alberta Environment decided it was necessary to undertake a detailed review of the existing research studies and to make use of the world literature reviews conducted in the Government/Industry Acid Deposition Research Program. The Department has completed the review and produced a new strategy for developing biomonitoring indices which will be used to monitor effects of low levels of acid-forming emissions over the medium- and long-term.

A new five-year plan for research in the oil sands area was initiated in 1986/87. The five-year research needs of this program are summarized in Table 1. This new program, which is described in the following sections, includes the following activities and will guide acid deposition research in northern forested areas of Alberta until at least 1991:

1. Evaluation of biomonitoring indices for terrestrial and aquatic systems.
2. Selection of biomonitoring methods and compilation of a data base over a deposition gradient of acid-forming emission.

3. Investigation of data to develop empirical relationships between emissions and biomonitor response.

The effects research program is designed to address the question:

> Is there measurable environmental damage due to acidification which can be monitored over the medium- and long-term?

If ecosystem damage is occurring, the hypothesis is that, "the pollutant loading and some corresponding quantitative measurement of damage will vary significantly along the deposition gradient". In order to identify an appropriate pollution gradient and determine deposition inputs for research, atmospheric research will determine sources, distribution, and deposition characteristics of the existing acid-forming emissions in the oil sands area. A monitoring program will be designed to determine the: (1) horizontal and vertical distribution of atmospheric gaseous and particulate matter within and above the forest canopy, and distribution to the soil and aquatic ecosystems; (2) determine wetfall deposition at canopy height and ground level, which will provide information on throughfall and available input to the soil and ground-water; and (3) microclimate of the receptor area.

Source apportionment studies and projects to upgrade emission inventories by collecting information on fugitive and low-level emissions are proposed in order to quantify and characterize the total emission burden resulting from Syncrude, Suncor, and other

Table 1. Five-year research needs for Alberta Environment Acid Deposition Research Program.

1. Organized evaluation and synthesis of existing information on atmospheric processes, deposition and receptor responses, as they relate to Alberta.

2. Description of regional (Provincial) scale meteorology and atmospheric processes.

3. Characterization of the physics and chemistry of selected Alberta point source plumes, with simultaneous ground level measurements.

4. Characterization and quantification of atmospheric deposition of beneficial and deleterious chemical constituents into Alberta ecosystems.

5. Identification, qualitative and quantitative characterization of sensitive receptors and processes related to acid deposition (laboratory and field).

6. Development of numerical methodologies to correlate atmospheric processes and pollutant deposition to effects on total ecosystems (i.e., receptor response), using an integrated approach. This should evolve into predictive capabilities to forecast air pollutant-induced ecosystem impacts.

7. Characterization and quantification of the effects of atmospheric pollutants on human/animal health.

8. Interpretation of program results to determine socio-economic and environmental consequences and mitigation strategies, which will assist decision makers in the development of public policy, regulatory guidelines and controls to ensure and maintain environmental quality, and human and animal health.

anthropogenic sources in the oil sands area. These studies and projects will enable Alberta Environment to assess the environmental impacts of present and future oil sands development.

Biomonitoring indices selected for impact assessment research will have to be evaluated first for their spatial and temporal variability. Vegetation research will involve testing the variability of biological indicators of acidification, such as needle length, needle retention, and seed viability. Provided that real impact-associated differences can be discriminated, the appropriate biomonitoring indices will be incorporated into a monitoring program and tested on a regional basis. A further restraint is that the monitoring indices must be feasible for use in medium-term (up to 25 years) programs.

Although some routine monitoring of soil parameters may be done for site characterization purposes, detailed monitoring of a wide range of soil parameters for detection of impacts in the medium-term is not considered advisable. Rather, soil effects research will concentrate on the identification of those soil components that buffer against long-term changes resulting from acid-forming emissions. A model will be developed to determine the buffering capacity of sensitive forest soils, and to determine what effects current and potential long-term loadings of acid-forming substances have or could have on soil chemistry. Predictions will be made as to how long, at assumed loading levels, it would take to cause major changes in soil chemistry, especially nutrient cycling capabilities.

An investigation will be made of the modeling techniques available for translating pollutant loading measurements or predictions to changes in water chemistry. Modeling techniques will be adopted to provide the following information:

1. Area loading (atmospheric) translated into predictable changes in water chemistry.
2. Time-frame for observable changes in surface- and ground-water chemistry.
3. Rate at which acidification and changes in water chemistry would proceed.

Government-Industry Acid Deposition Research Program

The formation of the Government/Industry Acid Deposition Research Program (ADRP) in 1985 is the result of a 10-year evolution of work to study and address the environmental consequences of acid-forming emissions on our environment. Public concern regarding effects of emissions from sour gas wells in southwestern Alberta on agricultural productivity and human health has been an integral part of this evolution. The ADRP is an $11 million undertaking by the Province of Alberta, industry (Canadian Petroleum Association, Alberta Power, Edmonton Power, Transalta Utilities) and the Energy Resources Conservation Board (ERCB). Research is focused on the agricultural effects of two principal gas groups, oxides of sulphur and nitrogen, and the overall effects on human health. The research on agricultural effects is jointly funded by Alberta Environment, industry (Canadian Petroleum Association, Alberta Power, Edmonton Power, Transalta Utilities), and the ERCB. The human health research was completely funded by Alberta Social Services and Community Health.

The first critical phase of the agricultural research component, which spans a period of 32 months, will involve:

1. An initial assessment of local and regional air quality and the potential impact of emissions on the environment. Three sites have been selected to monitor air quality parameters; a background site (Fortress Mountain, 100 km west of Calgary) to monitor air quality entering Alberta, and two sites in the study area (Crossfield, 30 km north and northeast of Calgary) representative of downwind and regional air quality.
2. An inventory of sulphur oxide and nitrogen oxide emissions in Alberta.
3. A world literature review in the biological sciences on the effects of acid deposition on vegetation, soils, and surface- and ground-waters. This will provide a comparative basis for a 'first order' assessment of the current status and potential for acidification in Alberta.

The last two tasks are nearing completion and reports should be available in 1987.

The human health component of the program was designed to address the specific and long-standing health concerns of residents in the southwestern towns of Twin Butte, Hill Spring, Mountain View, and Glenwood (Index Area) to determine if residents of the Index Area have the same status of health as the control area. Some residents of the Index Area have had long-standing health complaints which they attribute to sour gas plant operations. Two other communities served as controls - one exposed to air-borne pollution (Didsbury, Carstairs, Crossfield, Irricana) and one not exposed (Stirling, Raymond). A comprehensive health assessment was undertaken using questionnaires and physical examinations. Over 3600 residents were medically examined in the summer of 1985 by the team of doctors headed by Dr. W.O. Spitzer of McGill University. While the study did not deal with cause-effect relationships, it established that the health of residents in the Index Area was not significantly different from the Central area. The human health study, the Medical Diagnostic Review, was completed in June 1986 and the final report is currently being reviewed.

In addition to the Medical Diagnostic Review, an occupational epidemiology feasibility study will be conducted. This feasibility study will focus on the occupational work force of the sweet, sour and thermal gas industry, and attempts will be made to determine whether acute or chronic exposure to sour gas or its by-products has significantly affected the health of the workers. To ensure the scientific integrity of the program, scientific advisory boards comprised of international environmental and medical scientists will provide advice and peer review of the program. In recognition of the value of public views of the program, a public advisory board has been formed to facilitate involvement from and communication with the general public and environmental interest groups.

Western and Northern Canada LRTAP Program.

The departmental program provides the Alberta focus for the Western and Northern Canada Long Range Transport of Air Pollutants (W&NC-LRTAP) federal-interprovincial program which is investigating the medium- and long-range transport of air pollutants and their possible environmental effects.

The national and provincial governments of Canada have a tradition of joint action on environmental issues, resulting in cost-effective research and monitoring programs, and a uniform approach to problems regardless of provincial boundaries. The acid rain program in western and northern Canada is a good example.

British Columbia, Alberta, Saskatchewan, Manitoba, Northwest Territories, and Environment Canada first held joint consultations on the acid rain issue in 1980. By 1982, these provinces, as a consequence of their commitment to undertake research and monitoring programs to protect sensitive ecosystems from potential acidification, signed an agreement for a three-year research program covering the period 1982 to 1985. Program objectives include identifying current conditions in western Canada and providing information necessary to develop appropriate management strategies. The six program priorities and the major accomplishments attained during this period are delineated in the ensuing points:

1. Maps of areas with high aquatic sensitivity
    a. Methodologies-criteria for determining sensitive areas were developed.
    b. Preliminary maps were completed.
2. Maps of areas with high soil and geology sensitivity.
    a. Methodologies-criteria were developed for determining sensitive areas.
    b. Preliminary maps have been completed.
3. Monitoring of background acid precipitation.
    a. Standard protocols were developed.
    b. Monitoring network has been expanded to 62 stations.
4. Modeling of atmospheric acid deposition patterns.
    a. Long-range models have been applied to western Canada and deposition maps have been produced.
    b. Mesoscale modeling workshop was held to review and recommend mesoscale models for application in western Canada.
5. Emission inventories of SO_2 and nitrogen oxides.
    a. Inventories of SO_2 and nitrogen oxide will be regularly updated.
    b. Standardization of inventory data base will be pursued.

6. Monitoring of surface waters and soils in data sparse areas.
    a. Data base will be expanded to include data sparse areas.
    b. Standard water sampling methodologies will be pursued.

In 1984, W&NC-LRTAP agreed to continue cooperative action on a strategy for acid deposition to protect sensitive ecosystems from potential acidification. The identified research priorities for the subsequent three-year program from 1985 to 1988 provided for: (1) the continuation and modification of the monitoring activities for parameters considered to be of special significance in western Canada; (2) the establishment of deposition standards suitable for the sensitivity of the environment; and (3) the investigation of deposition models, and control models, which will allow evaluation of the impact of individual sources, and the most cost-effective manner of implementing a control program. These priorities are:

1. Monitoring of air, rain, and snow for acid forming emissions.
2. Emission inventory update.
3. Deposition criteria-target loading for western Canada.
4. Medium-range transport-deposition models.
5. Background ion concentrations and the influence of dust on precipitation chemistry and total deposition loadings.
6. Dry deposition measurements.
7. Monitoring of sensitive surface waters and terrestrial environments.
8. Evaluation of impact and assessment of control technology.

Projects undertaken by the Department to address the high priority needs identified by W&NC-LRTAP are highlighted in the Western and Northern Canada LRTAP annual reports.

Departmental Monitoring Program.

The Department is involved in an extensive monitoring program of soil, water, air and precipitation quality as part of its mandate to protect the environment. Monitoring of pollutants is conducted by line divisions within Alberta Environment to assist the Department in setting emission standards and in determining compliance with existing regulations.

Precipitation Quality

The precipitation quality monitoring program was initiated in 1978 by the Air Quality Control Branch, Pollution Control Division of Alberta Environment. The objective of the program is to monitor the chemical characteristics of rain and snowfall, which are representative of different regions in Alberta. The parameters of particular importance are the acidity (pH) of precipitation and the sulphate and nitrate deposition rates, which are directly related to the acid rain issue.

From 1978 to 1984, there were six provincial precipitation stations in the network. They were located at Beaverlodge, Calgary, Edmonton, Red Deer, Suffield, and Whitecourt. During 1985, three additional stations were put into operation at High Level, Cold Lake, and Kananaskis. It is intended that the three additional stations will provide information about the acid-forming chemicals borne to Alberta from other geographic regions.

Besides the nine-station provincial network, the Federal Government operates five precipitation quality monitoring stations in Alberta under the CANSAP (Canada Network for Sampling Precipitation) Program. The federal stations are located at Coronation, Edson, Fort McMurray, Lethbridge, and Rocky Mountain House. All stations in both networks collect monthly samples using automatic rain and snow collectors. Data collected by provincial and federal stations are directly comparable. Measurements of pH and major ionic concentrations are made on accumulated monthly samples. The quality of the precipitation is assessed based on the different parameters: (1) acidity from pH; (2) acid-forming emission contributions from sulphate and nitrate concentrations; (3) dust-related contributions from calcium and magnesium concentrations; and (4) salt contributions from sodium concentrations.

In 1986, the CANSAP Program was replaced by the CAPMON Program which collects precipitation on a daily event basis rather than monthly. There is only one CAPMON station in Alberta, which is located at Esther.

The monitored data from the federal and provincial networks supplement each other by increasing the total area in Alberta monitored for acid forming emissions and acid precipitation. The locations of all stations in Alberta are illustrated (Figure 1). The accumulated data base for this area (Fig. 1) allows detection of any significant changes in precipitation quality that may occur as a result of industrialization or long-range transport of the acid-forming pollutants.

Annual reports summarizing the data from the federal and provincial stations are published by the Air Quality Control Branch, Pollution Control Division of Alberta Environment.

Exposure Stations

The Exposure Station Program consists of 2,112 total sulphation and 1,276 hydrogen sulphide static exposure stations. These monitors are primarily located in and around urban centres, and industrial areas of the province. Data obtained in these stations are used to identify trends in sulphur deposition. Chemical analysis is performed by the Alberta Environmental Centre, and the results are expressed as mg SO_3 equivalents/day/100 cm^2.

Soil Monitoring

Long-term soil acidification monitoring in Alberta, carried out by Earth Sciences Division of the Soil Protection Branch, began in September 1981. From 1981 to 1984, eight monitoring plots (Fig. 2) were established at Rocky Mountain House, Fort McMurray, Twin Butte,

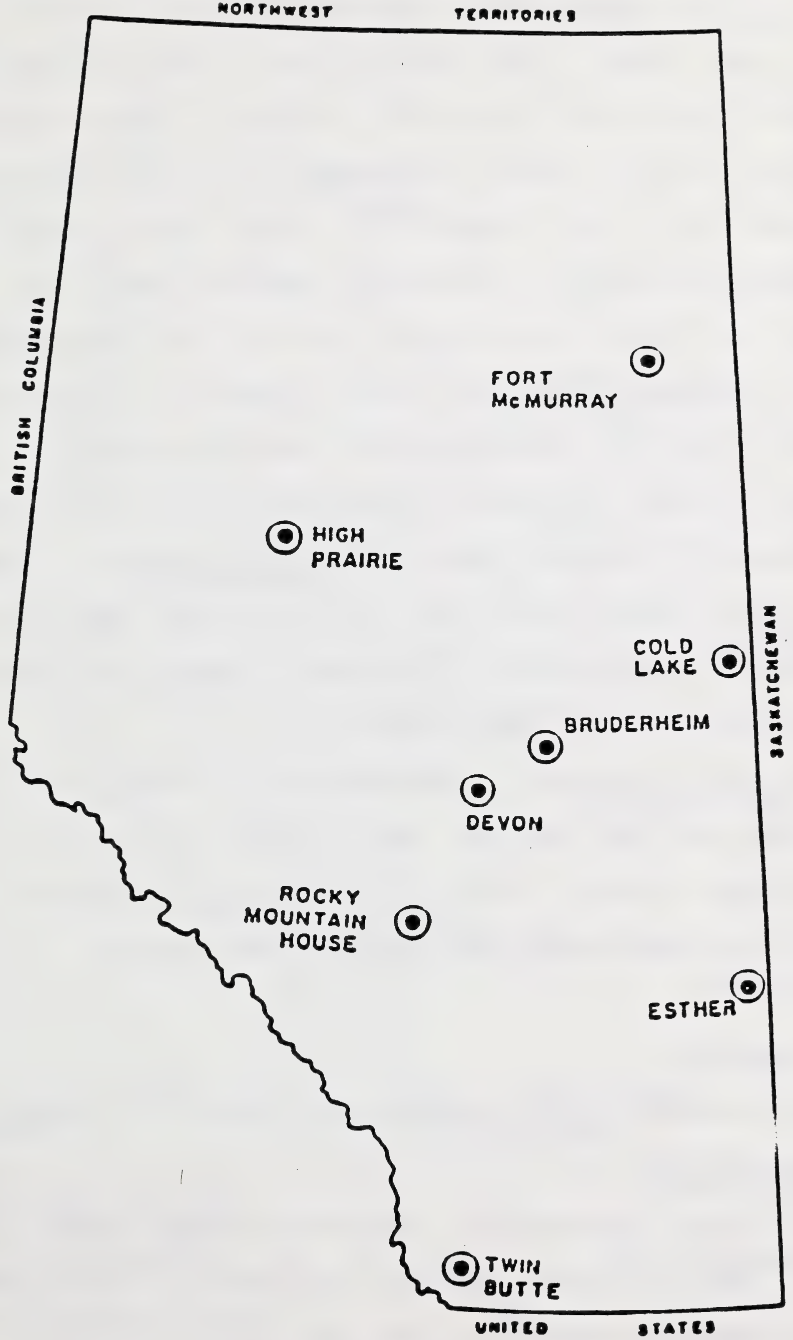

Figure 1. Location of precipitation quality monitoring stations in Alberta.

Cold Lake, Esther, High Prairie, Devon, and Bruderheim. This provincial program was established to provide an early warning of the potentially adverse effects of atmospheric acid deposition on soils. The objective of this program is to detect subtle changes in soil properties indicative of significant long-term changes in the ability of soil to sustain plant growth. All sites will be resampled once every four years. The two principal components of the monitoring program are the field sampling and the laboratory analysis.

Soils are the only matrix routinely monitored at these sites. It is planned to integrate total monitoring efforts (i.e.; vegetation, air quality, water quality and soil) at selected sites in the near future. A concerted effort will be made to combine activities of the relevant provinces and federal agencies.

An initial assessment of the sensitivity of Alberta soils to acid deposition has been completed. Maps depicting (1) potential of soils and geology to reduce acidity of incoming acid deposition, and (2) sensitivity of soils to acidic inputs have been prepared.

Field sampling.

Five characteristics were considered important to the selection of monitoring sites:

1. Areas identified as receiving maximum amounts of acid deposition were selected for sampling. These areas were downwind from major sour gas plants, oil sands plants,

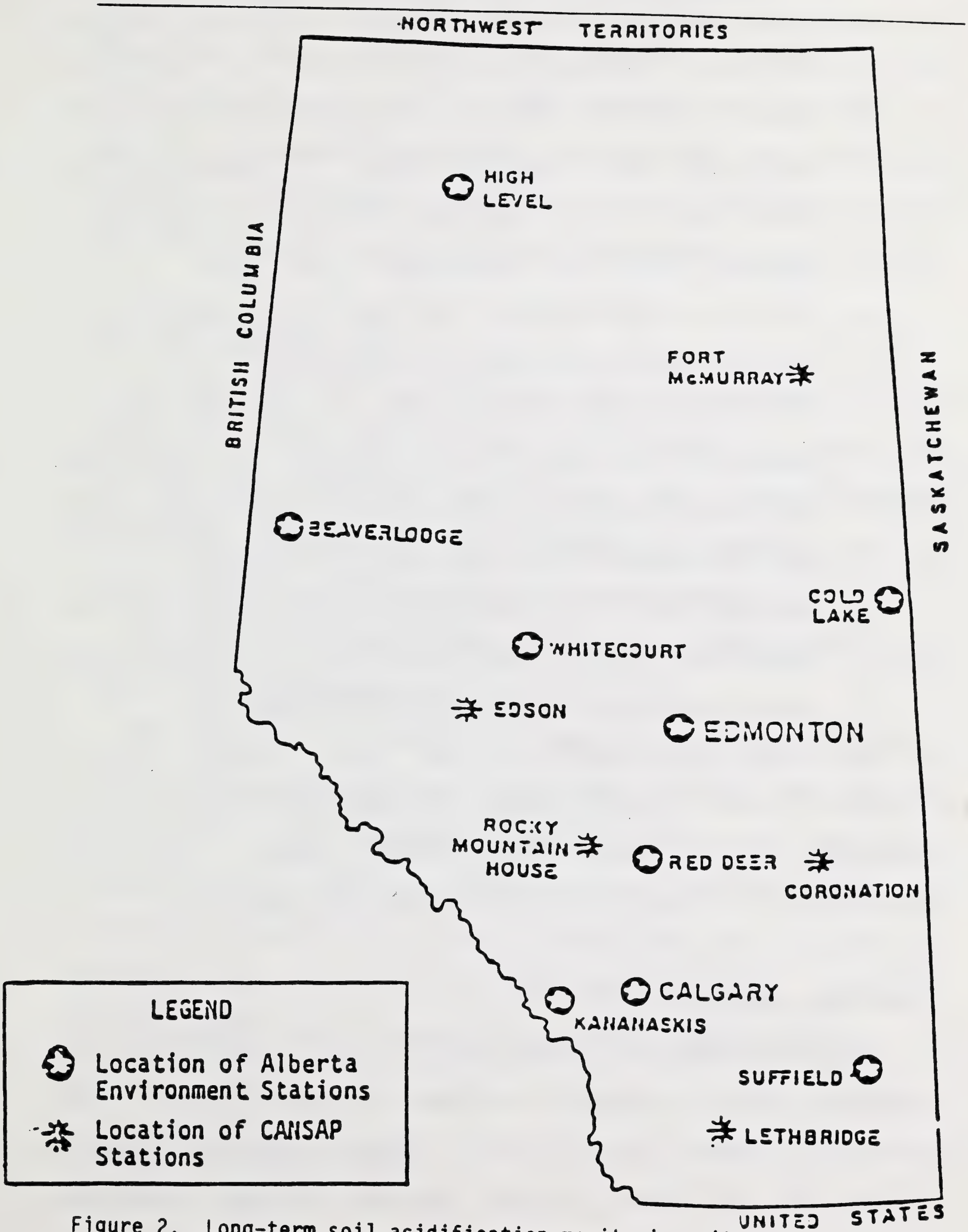

Figure 2. Long-term soil acidification monitoring sites.

coal-fired generating plants and heavy oil extraction plants. Care was taken to locate monitoring stations in areas where the localized effects of elemental sulphur dusting would not be an additional source of acid deposition.

2. The most sensitive soils were sampled in each area.
3. Plot areas were located on sites that were as homogeneous as possible with regards to soil characteristics.
4. Undisturbed native soils were selected. Six of the areas are forested and two are on native grassland. Cultivated areas were excluded because of the potential for soil acidification from farm management practices (e.g., fertilizers).
5. Each sampling site was secured, along with a buffer area, by registration with the Land Titles Office. As a precautionary measure, paired plots were established at each site.

The first two characteristics were those considered essential factors for an early warning system. The next two characteristics are important to the detection of subtle changes. The final characteristic is essential to allow for long-term monitoring.

Laboratory Analysis

Due to the many different effects of soil acidification, the laboratory analysis program is designed to measure changes in the status of a broad variety of soil chemical properties. Elements chosen for measurement include hydrogen, calcium, magnesium, potassium, sodium, aluminum, iron, manganese, sulphur, nitrogen, carbon and phosphorus. Soil testing procedures were selected on the basis of being generally accepted and appropriate for measuring the properties of acidic soils. Particular care was also taken to reduce the introduction of variability due to the laboratory analysis program.

Water Quality Monitoring

The Water Quality Control Branch of the Pollution Control Division maintains a fixed, long-term monitoring network on eleven river locations and the following Alberta lakes: Ethel, Baptiste, Nakamun, and Wabamun. All sites are sampled monthly and analyzed for a wide range of chemical constituents and indicators of acidity.

An initial assessment of the sensitivity of Alberta lakes to acid deposition has been completed.

This analysis has identified a number of areas in the northern upland regions, the Canadian Shield area, and the Rocky Mountain National Parks that are potentially sensitive to acid- deposition. Accordingly, our long-term monitoring network will be expanded to incorporate representative lakes in areas which may be subject to increased atmospheric loading of acid-forming substances. Subject to budgetary conditions, the expansion will occur in 1986 or 1987.

ANIMAL HEALTH

The Alberta Environmental Centre (Centre) is undertaking a study on the health effects of sulphur gases. The objective is to determine the effects of toxic or potentially toxic gases, vapours, particulates, and aerosols on animals and, by extrapolation, on humans. Current studies include the characterization of a 69 L inhalation exposure chamber, commissioning of a new 359 m^2 inhalation toxicology containment facility, studies on the acute toxicity of hydrogen sulphide, in vitro studies and techniques for evaluation of adverse effects of pneumotoxicants, implementation of an inhalation exposure system using 2 m^3 exposure chambers, and field investigations of possible effects on livestock (Coppock, 1986).

EMISSIONS CONTROL TECHNOLOGY

Concurrent with the above studies, work will be undertaken on control technologies to reduce emissions at their source. For some time now, the Centre has been involved in the assessment and development of a wide range of concepts-processes for the control of acid-forming emissions. Source industries such as gas processing, thermal power, oil sands, gas compressors, and waste incineration have been considered. A control using magnesium oxide to remove sulphur dioxide gas from emissions produced by a sour gas processing plant has been developed and successfully tested at bench-scale. A pilot-scale project is under consideration for funding jointly by Alberta Environment and Environment Canada.

Assuming that feasible control technologies will someday eliminate acid-forming emissions, and/or assuming emission sources in some areas may be decommissioned over the intervening period, the important questions will be:

Does the ecosystem recover on its own? If so, how fast?

Where possible, research will be focussed on these questions using field measurements in areas as the opportunities present themselves.

PROGRAM FRAMEWORK AND MANAGEMENT STRUCTURE

Overall coordination for the Departmental Acid Deposition Research Program has been provided by the Research Management Division with the advice and support of the Departmental Committee on Acid Deposition (DCAD). Membership in DCAD includes representatives from Pollution Control Division (PCD), Standards and Approvals Division (SAD), Earth Sciences Division (ESD), The Centre, Research Management Division, and other departmental staff. The DCAD addresses all activities, including research and monitoring, and ensures liaison between the Departmental W&NC-LRTAP and Government-Industry Acid Deposition

Programs. The objective of the liaison is to share technical knowledge and prevent duplication of efforts. To ensure that comparable, scientifically valid methodology is used in the departmental program, Alberta Environment has access to the Scientific Advisory Board of Government-Industry Acid Deposition Research Program.

A new system for approving research projects has been instituted by the department. Program Planning Committees have been set up to identify and prioritize research projects to address major environmental issues within the province. In the case of acid deposition, the DCAD, as one of its functions, fills the requirement for an acid deposition research program planning committee. Where appropriate, departmental project objectives and methodologies will be reviewed by external scientists and their suggestions incorporated.

CONCLUSION

The Acid Deposition Program for Alberta Environment should be viewed as a multi-faceted program of research, monitoring, and liaison activities, which is designed to address all concerns regarding the potential effects of atmospheric deposition in the province.

Protocol has been established and endorsed to integrate the department's program with the Government-Industry Acid Deposition Research Program. Efforts to effect this integration are now in progress. In addition, the department has made a formal commitment to continue participation in the W&NC-LRTAP program to 1988. It is likely that research and monitoring activities will continue well into the 1990s, as long as concerns of Albertans regarding acid deposition persist.

Acknowledgments

The author wishes to thank the staff of Alberta Environment for their efforts in developing and administering the department program and for their assistance in preparing this paper.

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PRODUCER OBSERVATIONS ON THE EFFECTS OF SOUR GAS IN CATTLE

Cliff Whitelock

I will present data that demonstrate that poisonous substances emitted from uncontrolled sour gas wells adversely affect cattle. The reason for this presentation is because I had the misfortune of having my cattle exposed to well emissions during two of these environmental disasters in the Drayton Valley area. The first environmental disaster was the sour gas well blowout that occurred on December 6, 1977 and was known as the Amoco Pacific Brazeau River 7-10-48-12-W5 or the Amoco 7-10 blowout. The second environmental disaster was the infamous Amoco Dome Brazeau River 13-12-48-W5 or Lodgepole blowout that occurred on October 17, 1982. The Amoco 7-10 well and the Lodgepole well are located 38 km (24 miles) and 40 km (25 miles), respectively, from my farm.

Observations of Farming Operations

We have a family farm located approximately 11 km (7 miles) southwest of Drayton Valley. In our cow-calf operation our calves are weaned in the fall, fed grain and sold as stocker cattle for feedlots. We have worked hard to develop top genetic quality cattle. We have a trustworthy reputation and a good market for our stocker cattle. We produce our own hay which consists of alfalfa-brome grass hay and barley.

Exposure to Sour Gas

In December 1977, my entire breeding herd was exposed for 27 days to the emissions from the Amoco 7-10 sour gas well blowout. However, I was fortunate that the Amoco 7-10 blowout occurred after my calves were sold. My cows were also exposed to emissions from the Lodgepole sour gas well blowout. The Lodgepole well blew on October 17, 1982 and was uncontrolled for 67 days. The well was not on fire for 27 days. Thus, my cattle were exposed to raw sour gas for 27 days, and sour gas well exhaust for 40 days. The calves were exposed to the blowout emissions for 14 days before weaning and for the duration of the blowout following weaning.

Effects on Calf Weights

The effect of sour gas on the weaning weights of calves is very important to livestock producers since calves are sold by the pound. Any effect sour gas has in decreasing the market weight of a calf costs the farmer money. In other words, lost income is the farmer's subsidization of the sour gas and oil industry.

The average weaning weights of my calves for the entire herd are given in Table 1 (Figures 1 and 2) from 1977 through 1986. The average weaning weight of calves for 1977 was 235 kg (517 lb). The 1977 average weight predates the Amoco 7-10 blowout. In 1978, the average weaning weight of my calves decreased from the 1977 values by 30.91 kg (68.0 lb) in 1978 and by 3.18 kg (7.0 lb) in 1979. In 1980, the average weaning weight exceeded the 1977 average.

The 1982 calves were exposed to the emissions from the Lodgepole well for 14 days before weaning and weighing, and for 53 days after weaning. The average weaning weight of the 1982 calves was 243.6 kg (536 lb) (Table 1, Figures 1 and 2). As yearlings, the 1982 calves averaged 287.27 kg (632 lb) and their average feed gain was 0.28 kg (0.61 lb)/head/day. Calves born in 1983 were weak and sickly. Weaning weights for these calves was 214.4 kg (473 lb) and their average rate of gain was 0.51 kg (1.13 lb)/head/day. Average weaning weight for the 1984 calves was 236.82 kg (521 lb), average yearling weights were 333.64 kg (734 lb), and the average daily gain for calves was 0.60 kg (1.31 lb)/head. The average weaning weight for 1985 calves was 269.6 kg (593 lb), average yearling weight was 379.1 kg (834 lb), and average daily gain was 0.74 kg (1.63 lb)/head/day.

The yearling weights, number of replacement heifers kept, and number of replacement heifers that were culled from the herd are given in Table 2 (Figures 3 and 4). Note that I had to cull 38% of the 1981 replacement heifers that were exposed to Lodgepole well emissions. These animals were culled because of infertility and because of the failure of their calves to meet my performance standards. It is important to point out that the cull rate of heifers that were not exposed to sour gas well blowout emissions was a maximum of 6%. My standard for culling did not change; it was a change in the performance of my heifers that changed the number of animals culled.

I have followed the cows in my herd that were exposed to the Lodgepole well emissions and this data has been brought up to date

(Table 3 and Figure 5). Calf weaning weights for 1983 were significantly different (P<0.05) from the other years; calf weaning weights for 1984 were also significantly different from other years, and calf weaning weights for 1985, 1986 and 1987 were significantly different from the other years.

Conclusions

The data presented in Table 1 and Figure 1 demonstrates that 27 days of exposure to emissions from the Amoco 7-10 sour gas well blowout had a marked effect on the weaning weights of my calves in subsequent years (Table 1, Figures 1 and 2). The weaning weights of my calves decreased by 30.91 kg (68.0 lb) in 1978, and by 3.18 kg (7.0 lb) in 1979. Sixty-nine days of exposure for my cows and calves in 1982 to emissions from the Amoco Dome Brazeau River 13-12-48-W5 or the Lodgepole blowout had a marked effect on my cattle. Because the Lodgepole blowout occurred a few days before the calves were weaned, the weaning weights were not decreased. However, the 1982 weight gains of the calves were decreased by 0.39 kg/head/day and the average yearling weights were decreased by 57.2 kg. The effect of exposing pregnant cows to sour gas in 1982 produced a 38.7 kg decrease in the average weaning weight of the 1983 calves, a 73.6 kg decrease in the average yearling weight, and a 0.16 kg decrease in the average daily gain. I have records on my cows that were exposed to the Lodgepole well emissions. Calves born to these cows in 1983 had a statistically significant (P<0.05) decrease in weaning weight (Table 3, Figure 4).

I have presented data which show emissions from sour gas well blowouts decrease the weaning weights and feeding performance of beef calves. Additionally, exposure of replacement heifers to emissions from sour gas well blowouts greatly increases the cull rate of these animals.

Acknowledgements

I wish to thank Dr. L.Z. Florence for doing the statistical analyses and Mr. Phil Henry for preparing the graphs.

Questions/Answers

1. Unidentified. Did the quality of your feed change from year to year?

   Answer. No. I have good feed. My hay averages 11 to 15% crude protein. I was also feeding grain. The hay was subjected to the same fallout as the cattle. I have good cows. A 1979 cow was the mother of the grand champion 4-H steer at the regional show in Edmonton. This steer sold for $2800.00. This same cow in 1983 weaned a 136.4 kg (300 lb) calf. In 1986 she weaned a 313.6 kg (690 lb) calf, which was born on February 6th.

   My own personal opinion is that emissions from the Lodgepole well damaged my cattle and decreased the quality of my feed. Newborn calves were sickly. Extra selenium shots were necessary to save the calves. Calves responded to selenium but not to other drugs. My livestock losses were one-third of my total losses due to the blowout. If I were not an established producer, the blowout would have put me out of business.

Alberta Agriculture should recommend to farmers in the area that they keep full and accurate records of livestock weights, herd health, hay production, metal building deterioration, and other expenses. Additionally, a panel similar to the arbitration board should be set up to assist farmers in settling sour gas-related claims. Our present system offers no alternative but to use the court system when negotiations fail. Most farmers cannot afford the time and money to go to court.

2. Unidentified. Did you get compensation for this?

Answer. Yes. I did go to the Farmer's Advocate and they intervened in the discussions of compensation. I did receive $30,000.00, which represented $0.20 on the dollar for my losses.

3. Unidentified. Did you notice any effect on your fences?

Answer. Yes. The fences rusted badly and are presently in bad repair. Some of the fences were not bothered at all. Other wire deteriorated totally. I have not had time to repair the fences.

Table 1. Effects of Sour Gas Exposure on Average Weights of Calves

Year	Weaning Weight[a]	Yearling Weight[a]	Daily Gain[a]
1977	235.00 (517)[b]	-	-
1978	204.09 (449)	-	-
1979	231.82 (510)	-	-
1980	243.18 (535)	316.36 (696)	0.65 (1.42)
1981	237.27 (522)	349.04 (768)	0.69 (1.52)
1982	243.64 (536)	287.27 (632)	0.28 (0.61)
1983	214.36 (473)	270.91 (596)	0.51 (1.13)
1984	236.82 (521)	333.64 (734)	0.60 (1.31)
1985	269.55 (593)	379.09 (834)	0.74 (1.63)
1986	278.64 (613)	-	-
Average[c]	253.1 ± 19.6	344.5 ± 26.6	0.67 ± 0.06

[a] Average weight in kg; () = lb.
[b] All of the cows included.
[c] Average of 1980-81 and 1984 to 1986.

Table 2. Effects of Sour Gas Exposure on Replacement Heifers

Year Born	Yearling Weights[a]	Number[b]	Number Culled[c]	Percent
1981	349.09 (768)	39	15	38
1982	287.27 (632)	17	1	6
1983	293.18 (645)	14	0	0
1984	338.64 (745)	32	1	3
1985	393.64 (866)	38	0	0

[a] Average weight in kg; () = lb.
[b] Number of replacements kept.
[c] Number of replacement heifers kept that were subsequently culled from the herd.

Table 3. Effect of Sour Gas on Cows as Determined by Calf Weaning Weights

		Weaning Weights			
Year	Number of Cows	Low	High	Mean	
1983*	43[a]	176.9 (390)	274.4 (605)	214.7±21.1[b]	(473.4±46.4)
1984*	41	185.9 (410)	351.5 (775)	260.8±37.2	(575.0±62.1)
1985	40	120.2 (265)	356.0 (785)	277.7±46.9	(612.3±103.3)
1986	31	172.3 (380)	353.7 (780)	287.5±40.6	(633.9±89.6)
1987	22	249.4 (550)	426.3 (940)	302.2±38.4	(666.3±84.7)
1988	19	263.0 (580)	376.4 (830)	313.8±31.7	(691.8±70.0)

[a] Calves from cows exposed to sour gas () = wt in lbs.
[b] Standard deviation.
* 1983 is significantly different from the other years. 1984 is significantly different from the other years.

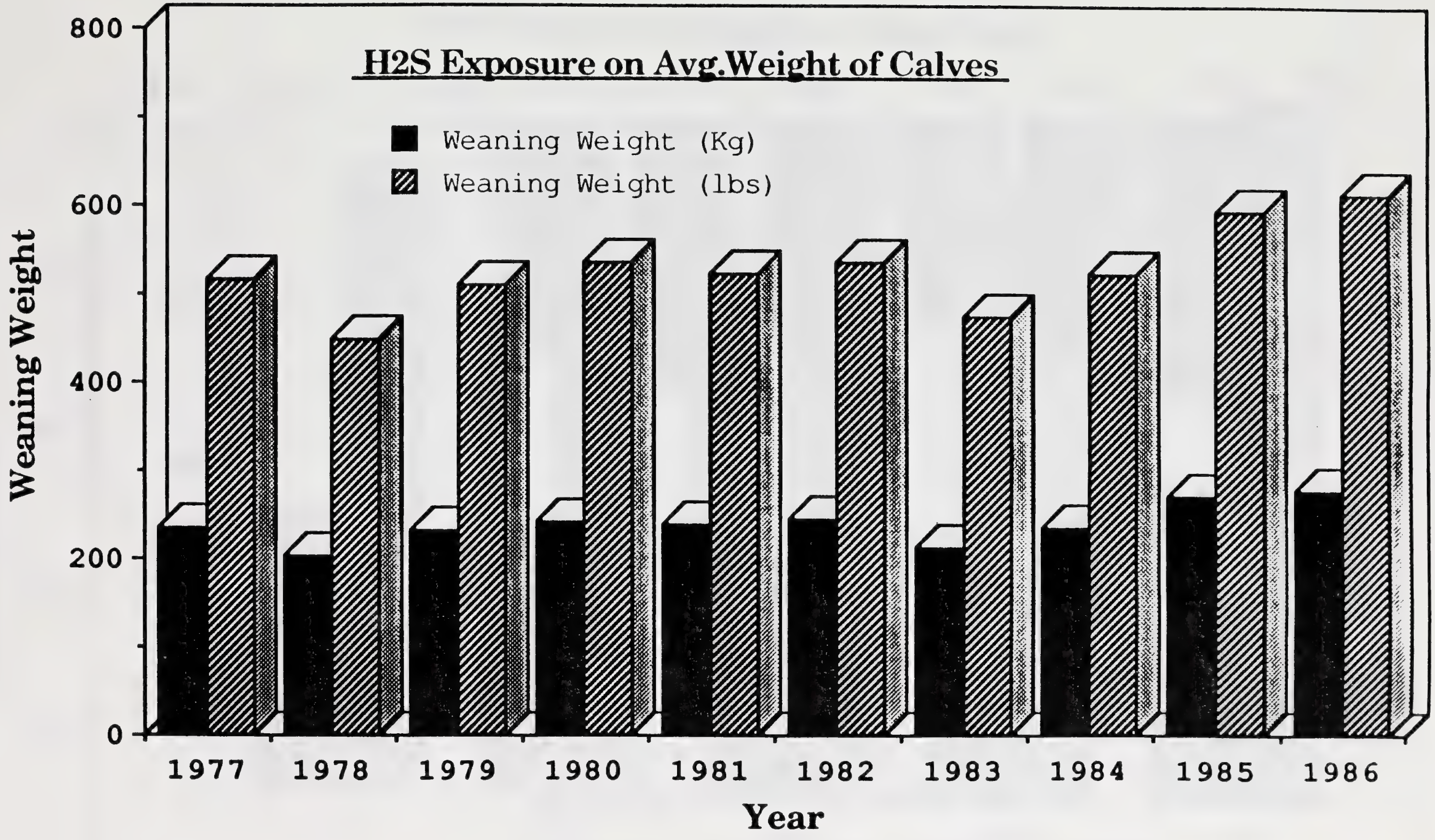

Figure 1. Bar graph of the average weaning weight of calves. Note that the weaning weights in 1978, 1983, and 1984 are decreased and are the result of the calves and cows being exposed to emissions from sour gas well blowouts.

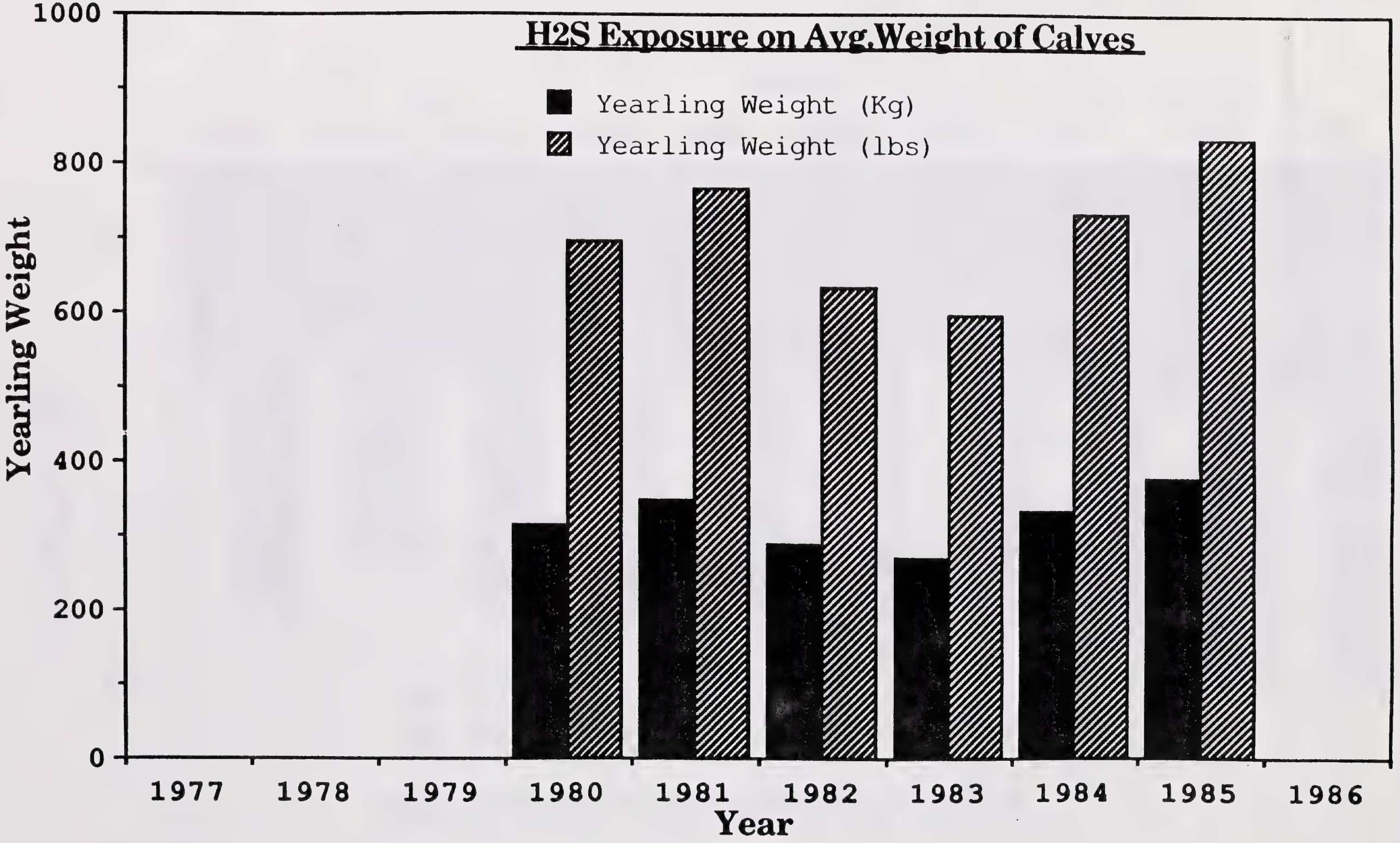

Figure 2. Bar graph of the average yearling weight of calves. The 1982 and 1983 yearling weights are decreased because of exposure to sour gas well emissions.

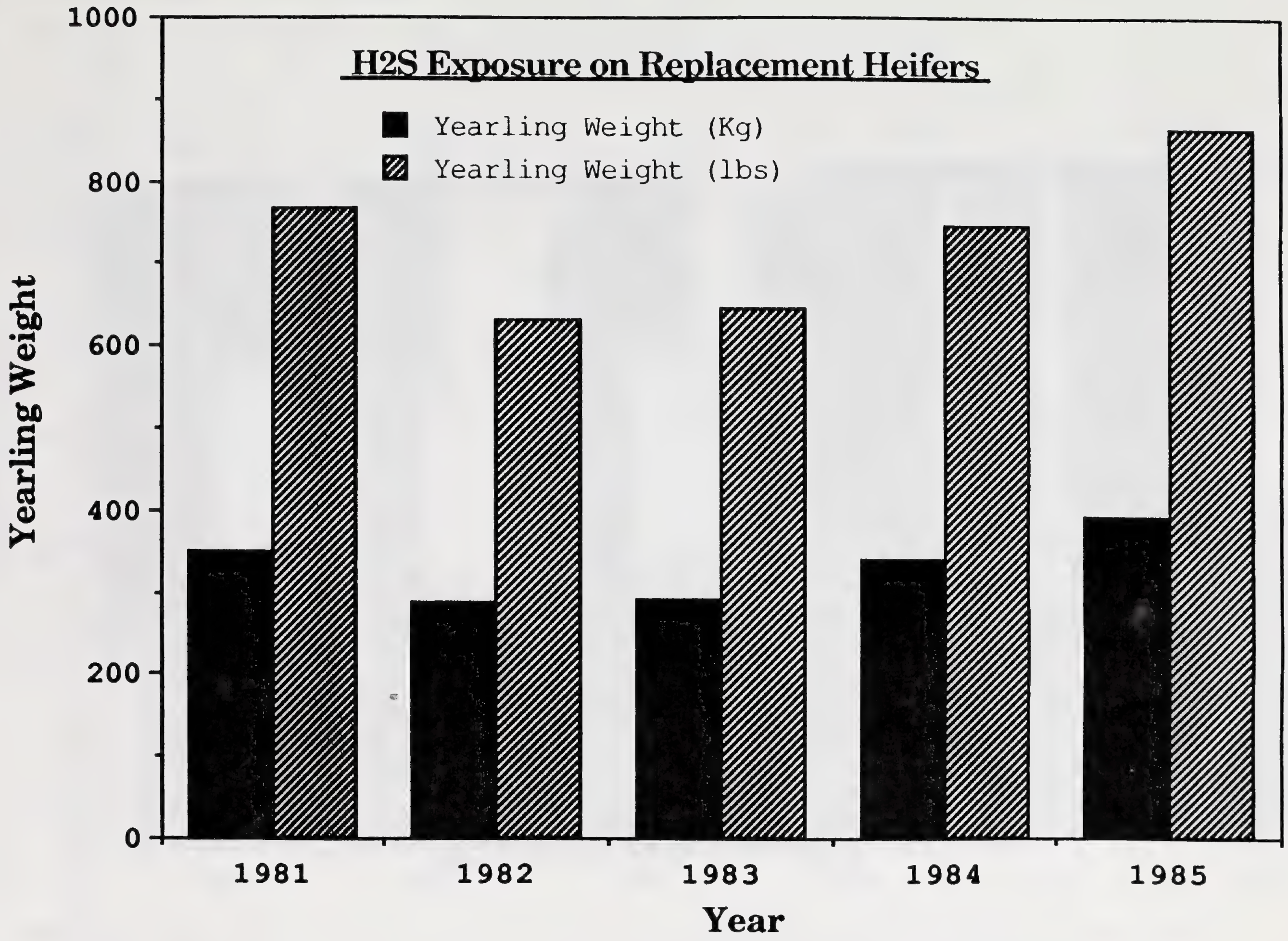

Figure 3. Bar graph of the average yearling weights of replacement heifers. The 1982 and 1983 yearling weights are decreased because of exposure to sour gas well emissions.

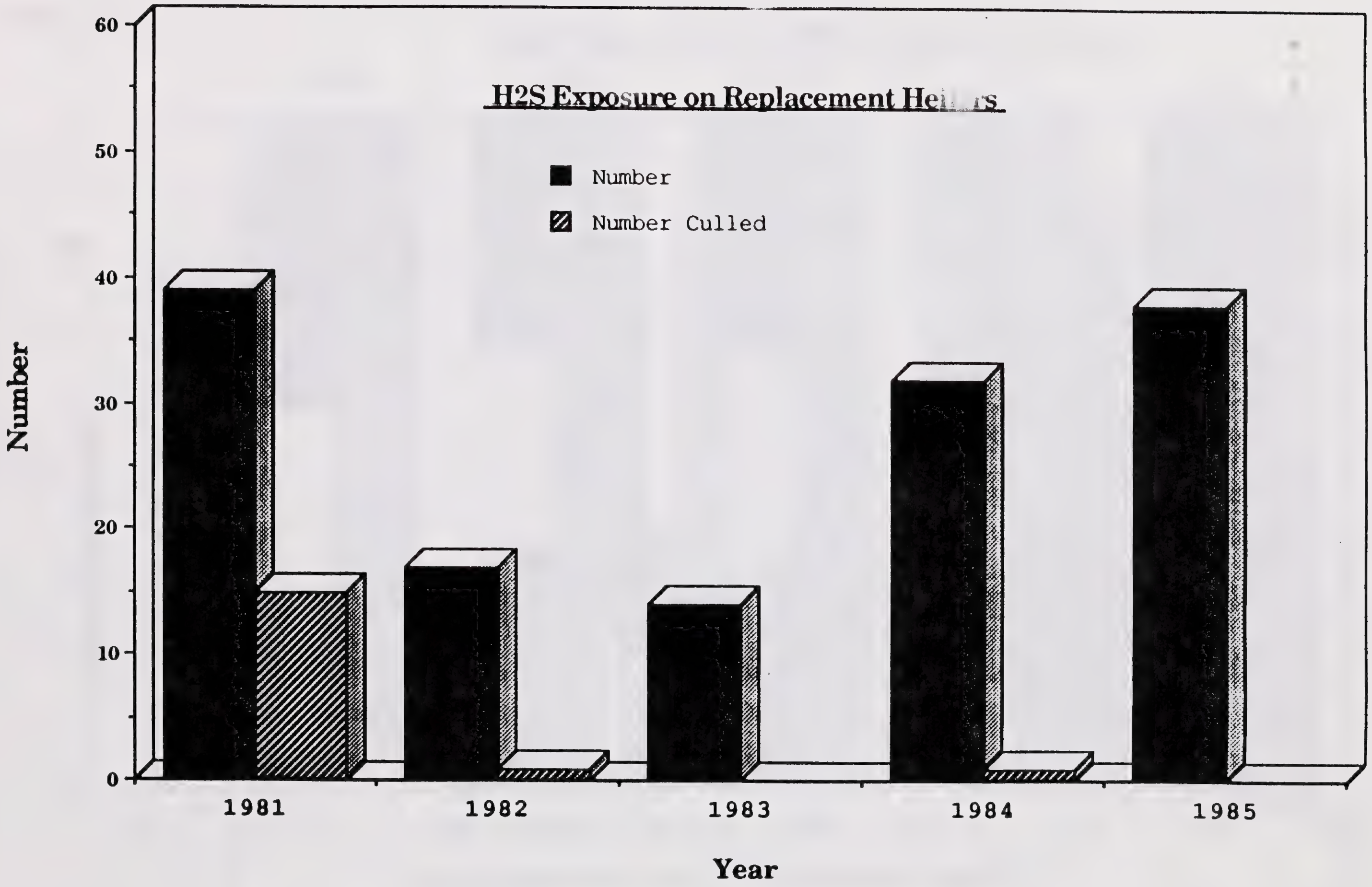

Figure 4. Bar graph of the number of replacement heifers culled from my herd plotted by year born. The number of animals culled is the accumulative number to December 1985. The large number of heifers born in 1981 culled from the herd is due to exposure to the Lodgepole well emissions.

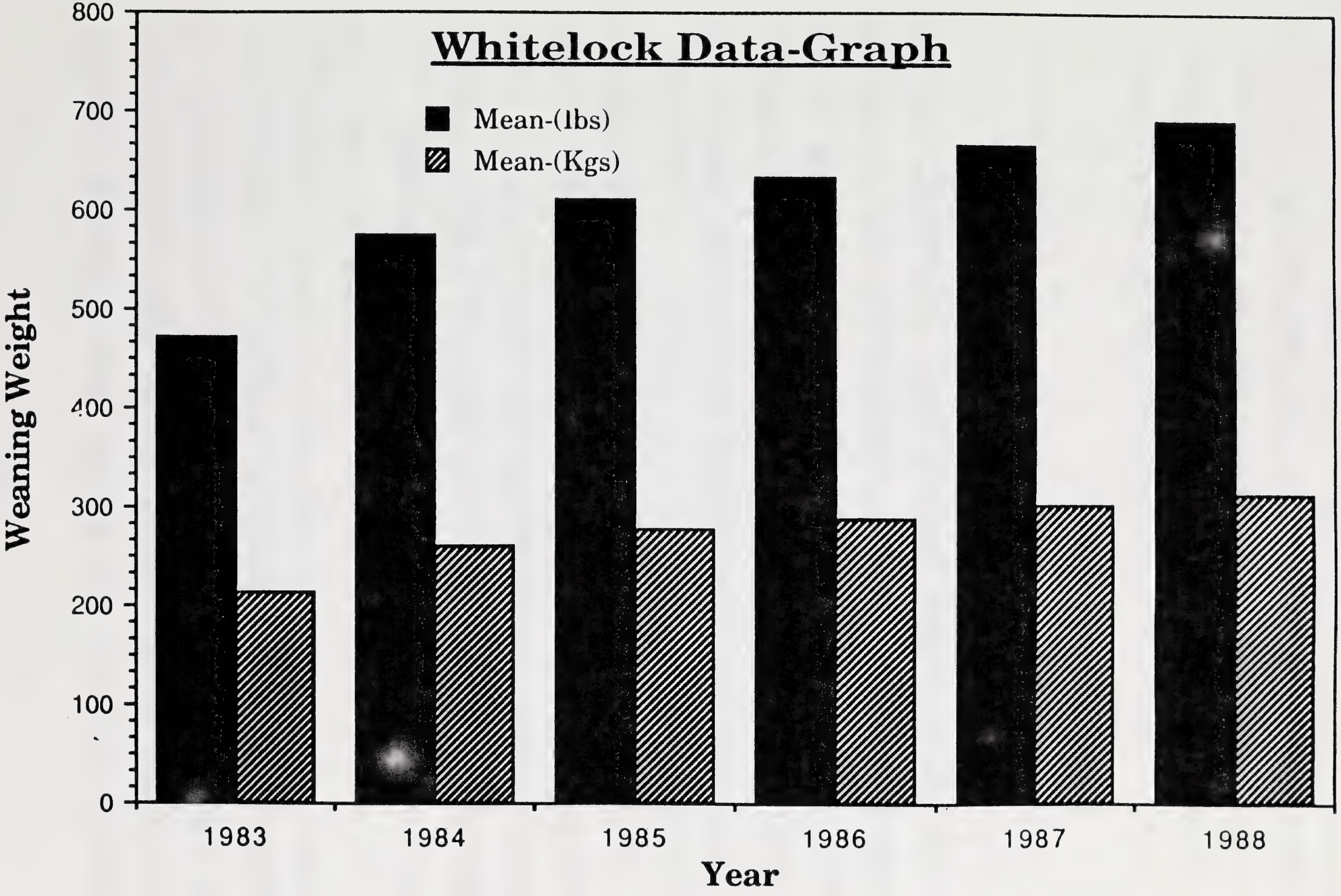

Figure 5. Bar graph of the weaning weight of calves born to cows that were exposed to emissions from the Lodgepole well. The weaning weights of the calves born in 1983 and 1984 are statistically different ($P<0.05$) from the other years and are also statistically significant from each other.

Producers Observations of the Long Term Effects of Acid Forming Emissions in Livestock

Diane McGlynn

INTRODUCTION

The majority of the livestock producers in the Pincher Creek area of Alberta are of the opinion that emissions from sour gas plants have adverse effects on our livestock. Additionally, we have anecdotal information to support our claims. We thank the Department of Agriculture and Dr. M. Kostuch for providing this opportunity to present our information.

In preparing this paper, my objective was to interview the majority of farmers located in the emission plume from the Shell Waterton Plant and the Gulf Sour Gas Plants (Figure 1) and to summarize their observations. The producers contacted were most supportive of this workshop and gave me their full cooperation.

The adverse effects of emissions from the sour gas plants on our livestock is not a problem that occurred overnight. Pollution from the sour gas plants has been in our community for a number of years. Some producers whose livestock have been adversely affected by sour gas plant emissions have said that they are tired of providing data to government officials, plant operators, hired consultants, university professors, and "you name 'em", over and over again. These producers reminded me, in a very direct manner, that information gathered for previous studies, ie. Sage Analysis, the John Prouse Inquiry, et cetera, have not seen the "light of day."

Interview Number 1

My first interview was with Mr. Jack Marcellus. He stated that there was no way that I could represent him fairly. Mr. Marcellus referred me to his 1969 affidavit, a public domain document filed in the Calgary Court House, which accurately describes the adverse effects of sour gas plant emissions on his livestock.

Interview No. 2

This farmer did not notice eye problems in his cattle until he moves his cattle to a summer pasture located close to a sour gas plant. Within two weeks following placement on summer pasture and exposure to fumes from the plant, approximately one-third of the herd showed signs of eye irritation.

Interview No. 3

A young girl noticed that when the air was bad her nose, as well as the noses of the horses and pigs, bled. She also observed that some of the animals with a nosebleed were hauled to the bone pile.

Interview No. 4

Mr. William A. Crook has lived on and farmed his place, located 3.8 km (6 miles) south of Pincher Creek, for the past 35 years. Mr. Crook was of the opinion that emissions from the sour gas plant had adversely affected his livestock.

Since the sour gas plants have been in operation, the lifespan of his sheep has decreased due to respiratory infections. The occurrence of pneumonia and lungers has increased with increased emissions from the sour gas plant. Additionally, he had not had problems with selenium deficiency in his cattle prior to the arrival of the gas plants.

Mr. Crook observed tearing in his cattle, especially when the air was heavy with fumes. Flies are attracted to the tears and introduce pink eye to his herd. Also, the occurrence of cancer eye in his herd has increased. This is associated with the irritation caused by the emissions from the sour gas plants.

Dugouts and other waterholes, especially in dry years, have become stagnant and dead. Although a dugout or waterhole may become stagnant, they do not usually die. As the warm season progresses, the fish, water shrimp, mosquito larvae, and other aquatic animals completely die out. We observe the same poisonous effects that scientists observe when testing bad water in the laboratory. In the spring, when the calves become old enough to drink from these watering places, scour problems occur. The observant person who has lived in this area for a number of years can see many changes in the way algae grow. In Mr. Crook's opinion, the acid forming emissions from the sour gas plants have decreased the quality of the water in his dugouts, and the bad water has adversely affected the health of his livestock.

Over the past 2 years, calves have been weak at birth. Over this two-year interval, a number of tests have been done by the various provincial laboratories but no useful answers or explanations have been given. For example, calves were sent to the laboratory for testing and feed was tested but no answers were provided. We have fed supplemental feed without results. Perhaps the carbon disulphide has been affecting the cows the same way it does pregnant women.

Interview #5

Mrs. Edith McRae and her family raise cattle in the plume area. The bottom line for Mrs. McRae is that fumes from the sour gas plants decrease the weight gain of their cattle. For example, two-year-old steers sold off the grass pasture in the fall averaged 485.46 kg (1068 lb) on 93 head. For the period from 1960 through 1968, the average weight on 165 steers was 472.27 kg (1039 lb). In 1969, the first year she sold steers which had spent more than 50% of their lives off the farm and out of the plume area, the average weight on 39 head was 490.91 kg (1080 lb). In all this time, the calves were fed hay and green feed. The yearlings were wintered on pasture and hay.

Mrs. MacRae observed breathing problems in the cattle following an outbreak of fumes from the sour gas plant. The problem was diagnosed as emphysema and pillowing of the lungs. This condition could have developed from an allergy to the fumes over a long period of time. Mrs. McRae observed that heavy breathing and some deaths occurred following a release of concentrated fumes from the sour gas plants. She considers this cause-and-effect relationship to be most significant.

Approximately one-third of the cows, which spend a month on a pasture located a mile east of the Shell Waterton Plant before going to the forest reserve, develop tearing and sore eyes, and a few may progress to pink eye. Their calves have developed a rough hair coat and started looking unthrifty. The eye problems have gone away after the cattle were moved to the forest reserve. The occurrence of cancer eye in the herd appears to be high. Each year, from a herd of 200 cows, they ship 3 to 6 cows (1.5 to 3.0%) which have developed cancer eye.

Over the past 2 years, the calves have been weak at birth. Also, over this two-year interval, a number of tests have been done by various provincial laboratories, with no useful answers or explanations given. For example, calves were sent to the laboratory for testing and feed was tested, but no answers were provided. The McRaes have fed feed supplemented with trace minerals without results.

Interview No. 6.

Janet Main, her husband and four children ranched in the Pincher Creek area for 10 years before the construction of the Shell Waterton Gas Plant (Shell Plant).

After the Shell Plant was put into operation, they realized that the plant had no industrial buffer zone. In fact, their ranch was the industrial buffer zone. The western boundary of their half section was within 183 meters (200 yards) of the Shell Plant. Because of the prevailing westerly winds, sulphur was blown from the loading area and the loaded railroad cars into their fields. Their farmstead (current cattle facility) was located 0.8 km (0.5 miles) west of the Shell Plant. In the Pincher Creek area, winds of 64 km/h (40 mph) are most common and storms with 160 km/h (100 mph) winds occur several times each year. Following these storms, enough sulphur was blown into their yard to give it a distinct yellow color. Yellow discoloration of their fields, located adjacent to the Shell Plant, was and still is common. Additionally, slugs of hydrocarbons from the Shell Plant have set their grass range on fire. Their family farm, their source of income, has become the inhabited and cultivated industrial buffer zone.

Based on their complaints, they negotiated with the Shell Plant to create a buffer zone and move their living quarters. These negotiations were most difficult because the corporate mentality at that time (1962-1964) did not recognize air or water pollution.

Therefore, negotiations were based on visible sulphur pollution and a documented fire hazard. They subsequently traded two downwind (east of the Shell Plant) quarters for two upwind (west of the Shell Plant) quarters owned by Shell. The two quarters east of the plant became a buffer zone. Even considering the grazing lease on the buffer zone, this relocation was a great financial inconvenience to them. They still use the old farmstead as the site of their cattle facilities. They calve cows in the barns, sheds, and surrounding fields.

The effects of the Shell Plant have reduced the quality of their lives to an intolerable degree. Their children suffer respiratory, digestive, and eye and skin irritations.

Mrs. Main summarized the effects of the sour gas industry on their family health and animal health; the damage to crops, pasture, fences and machinery, as well as water pollution.

A. Family Health

> The nature of our work dictates that we ride horseback, drive vehicles, or walk through fields located adjacent and downwind from the Shell Plant. We suffer irritation of our eyes, nose, lungs, and occasionally painful chest congestion from free sulphur kicked up while walking or riding through sulphur coated grass and bushes.

B. Animal Health

> Beginning in 1964 and continuing over the years, our animals have experienced an increased incidence of respiratory disorders

which we have associated with emissions from the Shell Plant. In September 1964, after the plant began operation, we found five cows and a bull dead of pulmonary emphysema. In October of this year (1986), two cows and two yearling heifers - on two different occasions - pastured in different fields, died from pulmonary emphysema. Over the years, these deaths have only occurred on fields directly downwind from the plant. This animal health problem is of great concern to us and I would welcome expert direction on it.

Other problems, which produce a lesser degree of financial stress, include photosensitization in certain animals (cows or calves) in the spring, scalding of the skin of newborn calves who come in contact with sulphur contaminated ground, and chronic coughing in many of our animals.

C. Damage to Crops and Pasture

The increased acidity in the soil downwind of the plant has resulted in great losses of crops and grass production. Attempts to get Shell Canada to rectify this problem by applying lime have been partially successful. In areas where extreme sulphur pollution has occurred, no grass can grow. Up to 1.6 km (1 mile) downwind of the plant, alfalfa production is greatly reduced.

D. Damage to Machinery

In the Pincher Creek area, the wind constantly blows, and the prevailing wind is from the southwest. The areas on our ranch most severely affected by rust and corrosion produced by drifting sulphur, sulphur dioxide and hydrogen sulphide are downwind from the Shell Plant. The wires of our fences are short-lived due to rusting. The wires below snow line, where a highly acidic situation seems to prevail, are the most affected. After haying certain fields, we must bring the haying equipment home to be thoroughly washed so that it does not rust and pit so badly.

E. Water Pollution

The water-course draining the Shell Waterton Plant settling ponds and a quarter section east of the plant flow through our old farmstead (presently used as our cattle facility). This water-way has been so devastated by sour gas plant emissions that the ground cannot support the growth of grass. The spring, which once was the source of water for the house, became sulphur-polluted and is no longer usable. The stream, before the Shell Waterton Plant was put into operation, was pure, cold mountain water. Since the Shell Waterton Plant has been in operation, the stream bed has become clogged with an orange residue and is so foul that it does not support life. Our cattle will not drink from it.

In summary, these points serve to illustrate the impact of the sour gas-sulphur industry on the rural environment. In our case, the Shell Plant has greatly jeopardized our ability to produce beef on a family farm. I welcome contact with members of this panel who can offer guidance to alleviate any of these problems.

Interview No. 7.

This is not an interview, as I will present my own experiences. My husband and I raise both sheep and cattle on our ranch located in the plume area approximately 24 km from the Shell Waterton Plant in Pincher Creek, Alberta.

A. Sheep

My husband, Fred, has raised sheep in this area for 25 years. He selects replacement ewes from the ewe lambs, and we also purchase a few bred ewes. We use registered rams purchased outside the Pincher Creek area.

Mineral imbalance is the number one problem in our flock. Our ewes crave minerals and we cannot satisfy them. White muscle disease is a serious problem and we must inject selenium to prevent this condition. We also inject vitamins A, D and E.

Our lambs have a high occurrence of respiratory problems. These occur in the newborn lambs at weaning time, and sometimes after weaning. We also have one lamb per season with a deformed heart. Our lamb crop should be higher. Compared with other farms located outside the plume area, which we have visited and purchased bred ewes from, we give our sheep exceptionally good care.

B. Cattle

Our cattle herd has been gassed several times with emissions from the gas plant. In fact, our calving grounds are located on a farmstead vacated by a family who moved away from the Pincher Creek area because of the fumes. Fume-filled air frequently drifts over our calving grounds. One morning the air over the calving pasture had very high concentrations of fumes. After the fumes decreased, we returned to feed the cattle and at that time we observed that not one of the 60 calves were up and running around. Needless to say, we were very afraid. It was not until much later that day that the calves got up. One of the calves had to be loaded into the truck and taken to the veterinarian where it began to recover after an hour or two.

Our cattle are pastured in the summer on native grass pasture. We feed cultivated hay and grain during the winter. We also feed a commercial concentrate which is supplemented with selenium. We feed minerals free choice. Vitamins A, D and E and vitamin E - selenium are injected. We have problems with white muscle disease in our calves and for the past 5 years we have injected the calves with selenium.

We have some calves which are born abnormal. These calves are born with crooked-looking limbs. Each year a calf is born with little hair. Last year, a stillborn calf was taken to the veterinarian for a necropsy. The chest cavity was filled with a bloody fluid and the cause was not determined. This concludes my remarks.

Acknowledgment

Appreciation is extended to Mr. Phil Henry for preparation of the map giving the farm location.

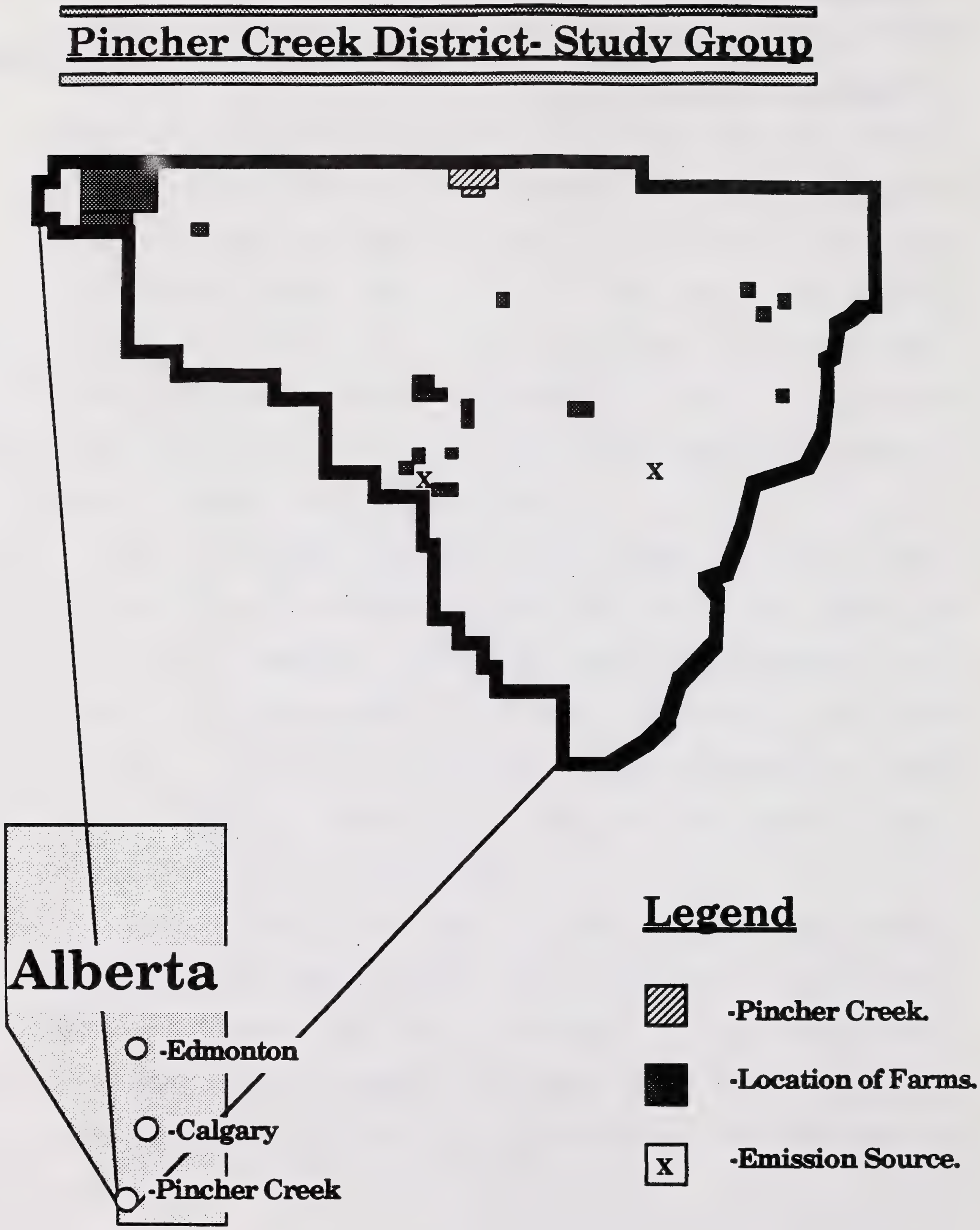

Figure 1. Map of the Pincher Creek district giving the farm locations.

PROBLEMS IN MAINTENANCE OF HERD HEALTH ASSOCIATED WITH ACID FORMING EMISSIONS

Martha Kostuch

Before establishing a veterinary practice in Rocky Mountain House, I was in private practice in Waterton, Minnesota. Soon after arriving in Alberta, I enrolled several dairy herds in a preventive medicine program. Based on my clinical experience in Minnesota, it soon became apparent that dairy herds in the Rocky Mountain House area were having a disproportionately higher occurrence of health problems than Minnesota herds with similar types of management.

Health problems which I found in dairy cattle in the Rocky Mountain House area were: unthriftiness, increased susceptibility to infectious diseases, reproductive problems, and "downer" animals. Because the health management program was oriented to theriogenology (veterinary gynecology), problems relating to the reproductive organs were the most apparent.

The following clinical observations are indicative of unthriftiness: animals doing poorly, reduced growth rate, and rough, dry haircoats.

Many animals also appeared to be more susceptible to infectious diseases. These animals often came down with pink eye, foot rot, and pneumonia. Some animals had a persistent, non-responsive diarrhea.

Reproductive problems observed in these herds were postpartum metritis-delayed involution and silent estrus. In the 10 herds in the program (Fig. 1), there was a 100% occurrence of post partum metritis-delayed involution. The metritis-delayed involution was characterized by lack of uterine tone, enlargement of the lumen, and was sometimes accompanied with a purulent discharge. Medical management of these cases was difficult because the majority of the cows required multiple treatments with antibiotics, and approximately 5 to 10% of the cows did not respond to treatment and were subsequently culled from the herds.

There was a 50% occurrence of silent heat in these herds. Silent estrus is characterized by cows having apparently normal ovarian cycles, as determined by rectal palpation, but not displaying the behavioural signs of estrus. Some cows with silent estrus will conceive if inseminated approximately 18 hours before ovulation. Because the behavioural aspects of estrus are lacking, the appropriate timing of insemination can be determined only by palpation of the ovaries. Thus, it is apparent that farmers could not determine when these cows were in heat and when to breed them.

Maintenance of the reproductive cycle of dairy cows is of major economic significance to dairy farmers. A dairy cow is normally on a 365 day reproductive cycle. The cow gives birth and this is followed by establishment of milk production. A dairy cow should be pregnant at 3 month postpartum, and be in lactation for approximately

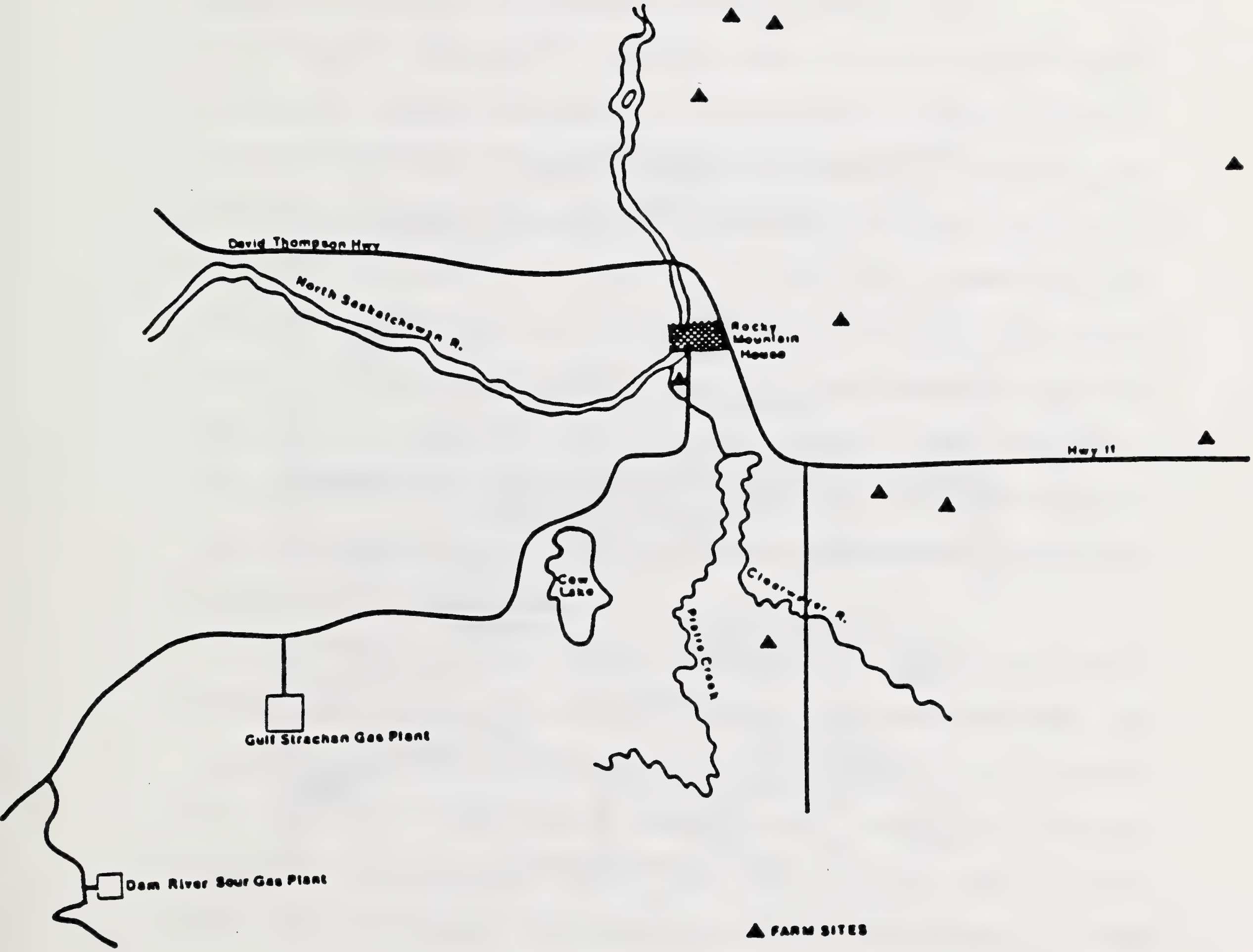

Figure 1. Map of Rocky Mountain House area showing location of dairy farms and sour gas plants.

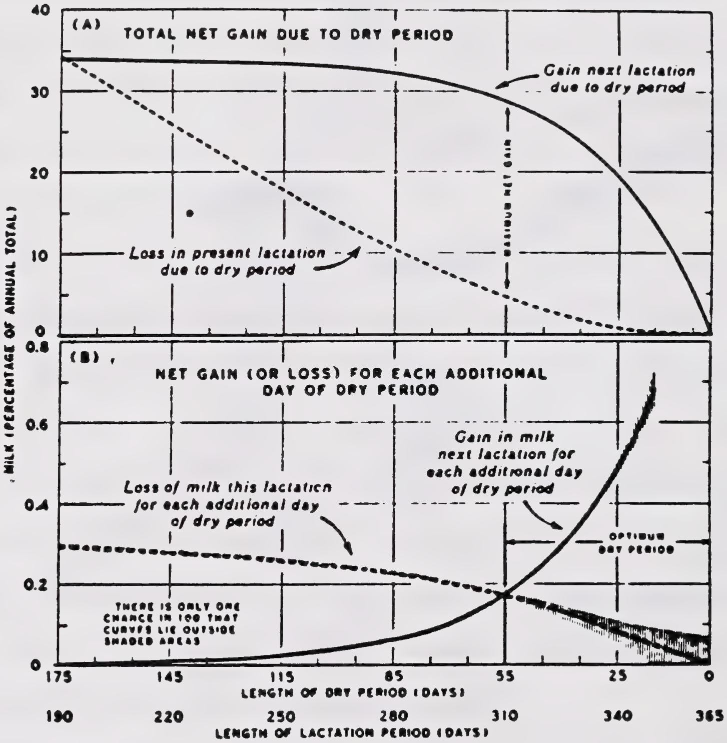

Figure 2. (A) Length of dry period and its effect on milk production; (B) Determination of the optimum dry period (From Klein and Woodward, J. Dairy Sci. 35:705. 1943).

305 days. After 305 days, lactation is terminated by not milking the cow. Parturition occurs following a dry period of approximately 3 months and lactation is re-established. The economic aspect of the duration of lactation and the dry period are given (Fig. 2).

In 100% of the herds in the Rocky Mountain House area on a health maintenance program, calving intervals exceeded 14 months (420 days), and 20% of the herds exceeded 15 months (450 days). Based on a price of $0.46/L of milk, the cost of the prolonged calving interval was a loss of $150-$250/cow. In addition to lost milk production, calf production was decreased and additional losses resulted from increased culling of cows from the herd. The cull rate from these herds was 30 to 35% as compared to the Alberta average of 25%. Because of reproductive failure, decreased calf numbers, and an increased culling rate, the producers were forced to purchase replacement animals which increased the economic loss.

These herds also had losses from apparent selenium deficiency. Cattle which cannot rise to a standing position unassisted are referred to as downer cows. The occurrence of downer cows and calves was increased. Some of the downer cows responded to selenium treatment. Excluding milk fever, there was a 1% occurrence of downer cows in all the herds. All downer calves died and pathologic findings were characteristic of selenium deficiency. Supplementing the diets of these herds with 300 to 400% of the recommended dietary selenium decreased the occurrence of downer animals.

In beef herds, unthrifty animals were observed. These animals were receiving diets which exceeded NRC recommendations. These herds also had calves which did poorly.

After extensive review, it was apparent that management of the dairy and beef herds was not a significant contributing factor to health problems. Two large sour gas plants are located southwest of Rocky Mountain House. The dairy herds on health management were located 25 to 50 km downwind of these plants. The maximum sulphur deposition is predicted to occur at a downwind distance of 25 to 30 km. It appeared that emissions from the sour gas plants were adversely affecting the health of these animals.

The Ram River Plant, the largest sour gas plant in Alberta (Fig. 1), was licensed in 1981 to emit 93.5 metric tonnes of sulphur/day. The Gulf Strachan Plant, until 1982 was licenced to emit 29.2 metric tonnes of sulphur/day. The combined total licensed sulphur emissions were 122.7 metric tonnes of sulphur/day, primarily as sulphur dioxide, plus other uncharacterized sulphur emissions.

After public hearings in 1982, licensed emissions from the Ram River Plant and Gulf Strachan Plant were reduced to 88.5 and 18.5 metric tonnes/day, respectively. Reduction of the sulphur emissions appears to have decreased the severity of reproductive and selenium deficiency problems in these herds. Although the occurrence of postpartum metritis-delayed involution in these herds is essentially 100%, the response of these animals to treatment has improved and uterine tone has increased. The calving interval in these herds has decreased to 13.5 months (405 days).

In summary, cattle in the Rocky Mountain House area experience an increased incidence of unthriftiness, increased susceptibility to infectious diseases, reproductive problems, and downer syndrome. It appears that emissions from sour gas plants are adversely affecting the cattle. Since the levels of emissions have decreased, the incidence of problems has also decreased.

References

Klein, J.W., Woodward, T.E. Influence of length of dry period upon the quantity of milk produced in the subsequent lactation. J. Dairy Sci. 1943. 26:705-713.

CLINICAL SYNDROMES IN LIVESTOCK ASSOCIATED WITH ACID FORMING EMISSIONS

J. Round

INTRODUCTION

There are only two people here who are survivors of the holocaust in Drayton Valley, namely, Cliff Whitelock and myself. We experienced the two Amoco blowouts! As a practitioner, I had hands-on involvement in these chemical disasters and I observed how the disaster was handled by government officials.

CHEMICAL COMPOSITION OF SOUR GASES

Although opinions abound on the toxicology of sour gas and the combustion products emitted into the atmosphere during the Amoco blowouts at Drayton Valley, little is known about the actual chemical composition. In the Lodgepole blowout, chemical analysis was limited to hydrogen sulphide. Yet professionals around the world have given opinions regarding the toxicity of these substances. Chemical disasters in Drayton Valley, Alberta, are not the same as a natural phenomenon in Rotorua, New Zealand. Some well-paid professionals have labelled those who become poisoned during these chemical disasters (sour gas well blowouts) hypochondriacs. I believe that my observations as a practicing veterinarian are the most valid medical data available on the toxicology of sour gas.

DISPERSION OF THE GASES (DOSE RESPONSE)

I wish to discuss some atmospheric conditions that increased the frequency and severity of toxicity of the substances emitted from the blowing wells and/or their combustion products. When the well was burning and producing a very complex mixture of toxic substances, which included sulphur dioxide (SO_2), the toxicity of the emissions increased. Temperature inversions and/or falling ambient temperatures such as the approach of evening and/or wind blowing in the same direction for several days appeared to cause the air to be saturated with sulphur-containing chemicals. This phenomenon was most apparent while the Lodgepole well was on fire. In fact, all of these weather conditions could have prevailed on a particular day and clinical signs of toxicity varied accordingly. In other words, the clinical signs of toxicity varied with the factors which increased or decreased exposure to toxic substances.

RESPIRATORY EFFECTS

In cattle and swine, especially calves and piglets, clinical signs of upper respiratory problems and eye irritation predominated. These signs included rhinitis, slight serous discharge from the nose, sneezing (piglets) and coughing (calves). Conjunctivitis was also observed (see "eye effects"). Although these clinical signs would suggest a respiratory infection, body temperatures remained normal and the animal continued to eat. There was virtually no response to medications. However, there was a remarkable improvement in these animals after the well was capped.

I have a client who is an exceptionally good cow-calf operator. Over a ten-year interval, the incidence of respiratory diseases in his herd have been essentially nonexistent. During the blowout, his calves, weaned two months previously, had signs of upper respiratory disease. Following capping of the well, these signs disappeared. He has not had respiratory disease in his cattle since the blowout.

Effects on the Eye

Clinical signs of eye irritation were also observed during the Lodgepole blowout and when Dome West Pembina started up their gas plant. Observed eye problems included reddening (erythema) of the conjunctiva (inside of the eyelids) and sclera (white part of the eye), congestion of the eye and some tearing. This condition was referred to by the farmers and myself as "red eye". Clinical signs of eye irritation were always accompanied with signs of upper respiratory irritation.

Effects on Reproduction

Aborted cattle fetuses were sent to the veterinary diagnostic laboratory and, after extensive diagnostic procedures, no known cause of abortion could be diagnosed. Because no diagnoses could be established, the producers and I could not justify the expense of sending additional aborted fetuses to the provincial laboratory. Keep in mind this was a full-scale disaster.

Over the years, veterinary practitioners have observed that cattle abortions, especially in the first trimester of pregnancy, generally increase with the first cold weather of the season. The Lodgepole disaster occurred concurrently with the first cold weather and confounded the identification of the effects of the disaster on first trimester abortions. However, when Alberta's best experts on diseases and other conditions which cause cattle abortions could not establish the cause, and when other toxic effects of blowout emissions have been observed, the chemicals emitted during the blowout must be suspect.

Additionally, it is known that carbon disulphide, a potential constituent in the Lodgepole well emissions, can cause abortions and infertility in women. Offspring born to women exposed to carbon disulphide can have reproductive problems. An abortion/infertility in a bred heifer from my own herd could be related to carbon disulphide exposure. Around December 25, 1982, our dairy cow gave birth to a heifer calf. This heifer was bred at 1.75 years of age and carried the calf until the third trimester of pregnancy (8 months). To follow up on the reproductive health of this clinically normal animal, she was retained in the herd but failed to have normal estrus cycles. Ovulation time with insemination was induced in this heifer with cloprostenol (Estrumate, Haver), and she conceived. This animal maintained pregnancy until the seventh month when she aborted.

Nursing sows were adversely affected by the emitted toxic substances. The sows showed clinical signs of eye and upper respiratory irritation and become aggressive. These aggressive sows were poor mothers and would trample and crush piglets. They would not relax while nursing their piglets; rather, they would bark, get up, step around, and then lay down and crush or injure piglets. In addition to stillbirths, weaning weights of the surviving piglets were decreased by about 33%.

There is still significant debate as to the effects on reproduction of substances emitted from the well and/or products of their combustion. However, no research institution this side of heaven can afford to fund a study of the magnitude of the chemical disaster that I have just described.

POTENTIAL EFFECT OF EMISSIONS ON STORED FEEDS

The reactive chemicals emitted from the well and/or formed by combustion could decrease the nutritional value of stored feedstuffs. Since sulphur dioxide is a reactive compound, it could chemically alter the essential nutrients in feeds. For example, sulphur dioxide has been used to reduce the amount of spoilage in silage. Cattle fed the sulphur dioxide treated silage started to die from a condition diagnosed to be polioencephalomalacia. This disease causes destruction of the brain due to a deficiency of thiamine. In fact, if diagnosed in time, treatment with thiamine will cure the disease. Further research on the treated silage has shown that sulphur dioxide destroyed the thiamine.

ECONOMICS OF SOUR GAS WELL BLOWOUTS

All of the farmers immediately downwind from the Lodgepole well noticed that calves and piglets, although they continued to eat, were unthrifty and gained weight at a lower rate. This is the bottom line and represents a substantial loss to the livestock producers.

Cancer

Although this observation may meet with controversy, I had a gilt, in gestation during the blowout, that developed lymphosarcoma.

CONCLUSIONS

A large scale chemical disaster occurred in the Drayton Valley region during the Amoco sour gas well blowouts. The medical findings given in this paper, although labelled anecdotal by some, provide substantial medical evidence that the complex substances emitted from the sour gas wells and/or their products of combustion were poisoning animals in the Drayton Valley area.

QUESTIONS AND ANSWERS

1. Unidentified: What type of cancer is lymphosarcoma?

   Answer: Cancer of the lymphoid tissue.

2. Dr. R. Christian: Comment. Lymphosarcoma in pigs is seen in scattered locations of Alberta. I think that you have to be very careful in drawing any association between observing lymphosarcoma in one pig potentially exposed during gestation to sour gas.

Answer: I sent specimens to the provincial laboratory. The pathologist informed me that it was very unusual to have a case of porcine (swine) lymphosarcoma in Alberta.

Dr. Christian: I think it is just coincidental with the blowout.

3. Unidentified: Could you comment on the heifer?

Answer: The cow carried her during the blowout. This heifer was born weak and it took a great deal of veterinary care to get her going. What would have happened if the Lodgepole blowout had occurred during the March to May interval or during calving season? Perhaps, hopefully, we will never know.

4. Unidentified: What concentrations of hydrogen sulphide were measured? How can toxicity be associated with exposure?

Answer: There is no test that can give conclusive proof that sour gas produced toxicity. At this meeting, we have scientists and those of us who observed the effects of the gas by being subjected to it. There were no machines which measured the complex mixture of chemicals we were exposed to and gave us a printout of so many parts per million of this or that. We used a sensitive biological assay; our eyes and noses burned. An important point is that our own bodies and our livestock were the test animals. Why do you not rely on people living in the area? Persons in the area during the blowout, with burning eyes, upper respiratory problems, would go to their family doctor. A common - too common - diagnosis was that you have the flu. When the well was capped, the bloody flu went away. This "flu" was, in fact, the toxic effects of the well emissions and make no mistake about it. If we were rats in an exposure chamber being examined by scientists, we would have been diagnosed as being poisoned by the blowout emissions, a full scale chemical disaster.

5. Unidentified: How can blowouts be prevented in the future?

Answer: I think the occurrence of blowouts will increase. There does not appear to be a penalty against oil companies for sloppy drilling operations. As far as I see, they only get a slap on the wrist-in-public as an embarrassment. I think there should be a severe penalty inflicted on these operations, especially if a second blowout occurs. Oil companies must be taught a lesson. They always use the excuse that we are dependent on them for jobs. However, as soon as the oil prices drop or new technology comes along, they rapidly get/got rid of their employees. On medical issues, as I mentioned earlier, they purchase opinions from around the world.

6. Unidentified: Mr. Whitelock and yourself have indicated that there is a uterine effect of sour gas; that is, the fetus in the uterus is affected. I wonder if you would speculate on what some of the causes might be.

Answer: Well, this is very difficult to say. In a problem like abortion, the circulation to the uterus may be impaired and enough oxygen would not be delivered to sustain life. Emitted chemicals could alter hormones or cells that make hormones.

I forgot to mention that decreased litter size was observed. Some farmers averaging 10 to 12 piglets/sow before the blowout hit would get 3 live piglets and 7-9 dead. This was observed during the blowout. Sows which were bred and farrowed subsequent to the blowout produced 10-12 live piglets. Dead piglets were sent to the provincial laboratory and the experts found nothing.

7. Unidentified: What did the laboratory check for?

Answer: Any possible cause of abortion. They could not find a cause for the stillbirths. Also, as I understand, the fellow who was killed by sour gas when they were trying the cap the well did not have any significant pathological lesions. In sour gas poisoning, there is really no evidence to show cause of death.

8. Dr. A. Lopez: You are suggesting that hydrogen sulphide in the blood may have caused oxygen starvation to the fetus?

Answer: Yes. This has been demonstrated in piglets for carbon monoxide.

In humans who are exposed to poisonous gases, researchers compare cell types washed from the lungs. However, cattle will not lay there and let you do whatever you want.

I want to re-emphasize. I just do not believe people really understand how serious, i.e. how dangerous, one of these blowouts is. If these chemical disasters happened in the wrong places, maybe - God forbid, in Calgary or Edmonton, the response would be much different. Drayton Valley is out of the way, politically a safe distance from the bulk of the population.

9. Unidentified: Were problems observed in horses?

Answer: There did not seem to be problems with horses. I did not see that many horses.

10. Dr. Kostuch: What are your thoughts on low level (concentration) emissions over a long period of time? Do you feel that there is going to be an effect, that is, eventually down the line?

Answer: After the two blowouts were shut in, Dome started up the West Pembina Gas Plant. During the first two months of operation, there were a number of upsets. The plant upsets were finally confirmed by the ERCB. Naturally, when the plant is upset, they go to flare. The flare is as intense for emissions as when Amoco's blowout was going. At the time the plant was starting up, I had 100 feeder pigs and they were doing quite well. When the sulphur dioxide emissions started coming from these flare stacks, the pigs developed "red eye". We had a session with the ERCB and they told us that we were hypochondriacs. Were my pigs hypochondriacs also?

We again had high sulphur dioxide levels this past fall. This was interesting in that for almost a month every night at 18:00 h the flare stack would start going and go all night. Instead of phoning the ERCB, I phoned the plant operator and asked him if he would be kind enough to reduce his stack emissions so we could sleep at night. For the balance of October, there was no more flaring. However, we had had enough sulphur dioxide and moved from the farm to town. I am convinced that people get sensitized to these sour gas emissions. Your lungs become sensitized to the emissions. Because of the adverse effects on your body, you detect these odors before unsensitized persons do. People who work in the oil and gas industry do not complain. These persons are afraid of being "canned" or run the risk of having a close relative fired. Drayton Valley is an oil town.

11. Unidentified: Would you comment on human health?

Answer: No, I will not comment on human health. I will comment on the effect of calves being downwind from a sour gas plant. I practiced in the Buck Lake area. The Candell Sour Gas Plant is at Buck Lake. Calves downwind from the plant were deficient in selenium. There were always more cases of white muscle disease south of the plant. West of the plant, the incidence of white muscle disease was very low.

THE EFFECT OF GAS & OIL WELL BLOWOUT EMISSIONS ON LIVESTOCK IN ALBERTA

B.E. Beck

INTRODUCTION

In Alberta we are faced with either the massive release of a hydrocarbon mixture rich in hydrogen sulphide when a sour gas well blows, or effluent from a gas plant. The resulting polluted atmosphere, reeking of rotten eggs, drifts across a land populated by moose, deer, cattle, pigs, farmers, and city dwellers. When faced with exposure to toxic gases, repulsion, fear, paranoia, or ambivalence are created, depending on one's state of mind. However, the problem faced generally is not one of acute toxicity, but one of subacute or chronic toxicity. Poisoning is not acute because the gas is diluted by the atmosphere before it reaches livestock. Exposure may last a month or more and may produce a syndrome indistinguishable from common disorders of flu, malaise, mood changes, and in the case of animals, lack of production or decreased production.

To date, the majority of documentation of acid forming emissions on livestock originates from observations made by the public involved. It is not supported by scientific, objective, or measured observation. Because acid forming emissions contain highly toxic substances, the only real documentation deals with the acute lethal or sublethal effects of the highly toxic components, especially hydrogen sulphide (H_2S). The problem arises when livestock producers turn to the government for answers as to what has happened, or is going to happen, to their animals. The problem is further compounded because their inquiries are prompted not only out of concerns for safety. They also want compensation from and retribution against the company responsible for turning their pristine environment into a less pleasant existence.

To adequately explain what may or does happen is difficult for three reasons. First, scientific and medical literature refers mainly to humans and laboratory animals rather than livestock. Secondly, what is often said to happen in exposed livestock is derived from extrapolation from humans and laboratory animals. Some of the effects may be significant, but they are not dramatic or observable. This means the effects must be measured by epidemiologic examination rather than direct observation. Third, we are not able to clearly define the chemical composition of the toxicants, nor to define the conditions under which the livestock were exposed. In the case of a sour gas well blowout, massive quantities of gas escape from the ground. The escaping gas contains high concentrations of hydrocarbon, powerful reducing agents such as H_2S, minerals, and water under extremes of temperature and pressure. Upon release into the atmosphere, this complex mixture undergoes complex chemical reactions, such as concurrent reactions with oxygen and photo decomposition by ultra violet light. Therefore, it is easy to imagine that a large number of chemicals (poisons) may exist.

Additionally, little information is available on the chemical composition of stack emissions from sour gas plants. Sulphur compounds appear to account for the toxicity of emissions from sour gas plants.

What actually happens to animals in a blowout or from emissions from a gas plant?

What can a livestock producer expect to see in animals exposed?

The following comments are derived from my interpretation of the literature and extrapolation to animal health, from my observations in prior blowout investigations, from farmers' comments and emperical observations. The following explanations refer to exposure levels livestock would most likely be exposed to in a blowout situation; that is, a maximum of 10 ppm for no more than 8 hours or occasional peaks of 20 ppm or less in a blowout situation.

Effects from Gas Plant Emissions

Gas plants expel principally sulphur dioxide and possibly organic substances. Extensive analysis has revealed that no metals are generally expelled. In past years, especially during temperature inversions, sulphur dioxide (SO_2) concentrations were sufficient to produce runny eyes in cattle. Because of the acrid smell of these emissions, it is not difficult to relate ill health in animals to the effects of exposure.

Other coincidental complaints were also observed. These were loss of production, diarrhea and abortion. However, these problems are normally found in a livestock operation. Bolstered by findings in the most recent human study conducted on residents in the Pincher Creek area, it is difficult to suggest any real effect on livestock health that has resulted from exposure to effluents from normally operating gas plants (Spitzer et al. 1986).

Of more real concern is the environmental contamination of soil and water from sulphur compounds. In most areas in Alberta, this problem is minimized by the highly buffered alluvial soils. However, the concern remains that acid forming emissions have an effect on trace mineral availability, particularly selenium and copper. The most sensitive element to sulphur contamination is copper, and this does not appear to be affected. Selenium, although often incriminated, would require massively greater amounts of sulphur to cause a deficiency in livestock. At the present time, I cannot suggest realistically that livestock health is adversely affected by the normal functioning of a sulphur recovery gas plant under the present rules of operation.

The following description applies specifically to blowout emissions, and would also have some applicability to gas plants.

Local, Surface or Cutaneous Effect.

Blowout emissions may contain oxidant gasses as well as H_2S. These products have an irritating effect on mucous membranes, causing runny or watery eyes known as excess lacrimation in livestock. The condition is mild and clears up spontaneously, but can be considered as evidence of exposure. Under extreme exposure to H_2S, the cornea may become cloudy and even ulcerate. Experimental animals with ulcerated corneas have healed up with only a small scar remaining. A major concern may be the concomitant occurrence of pink eye, a bacterial infection. Pink eye produces clinical signs similar to H_2S, and the two conditions could be easily confused. Differentiating an outbreak of pink eye, in the summer during a blowout episode, from sour gas toxicoses would be extremely difficult. Bacteriologic culture and other laboratory procedures would be necessary. It has not been established, but it is possible that H_2S exposure would predispose livestock to pink eye or at least make it worse.

Respiratory Problems.

Respiratory problems did appear to be of concern in blowouts. Anticipated respiratory aspects of sour gas toxicoses would be mild upper respiratory tract inflammation which would produce no chronic or long lasting effects. The respiratory irritation can be caused by the irritant effect of H_2S and also the aerosol hydrocarbons (condensate). The irritating effect of H_2S is seen as coughing and shortness of breath or quicker respirations, and in feedlot cattle it may give the appearance of an impending outbreak of shipping fever pneumonia. The animals do not run a fever and the problem ceases as soon as exposure ends. It may produce susceptibility to a higher incidence of secondary pneumonia. The paralyzing effect of H_2S on respiratory cilia and immune function has been documented in laboratory mice. To my knowledge, no reports of unaccountable or unusual respiratory episodes of disease coincidental with exposure have been documented.

Reproductive Problems.

Abortion, infertility, and congenital defects are areas of concern. Considering the efficient detoxification of H_2S in animals, it would seem unlikely that sufficient poisons would reach the fetus prior to killing or severely affecting the dam. Hydrogen sulphide is rapidly detoxified by combining with oxygen in the blood to form thiosulphate and sulphate. It is only when sufficiently high levels are achieved that H_2S can persist long enough to reach the brain to produce loss of consciousness and paralyze respiration. It would seem most improbable that H_2S could persist as sulphide in the blood long enough to reach the fetus. Some publications have incriminated H_2S as causing birth problems, but this information was based on dual exposure to H_2S and carbon disulphide. Carbon disulphide, a constituent of sour gas, is known to have an effect on the fetus. Fears of reproductive effects were raised by environmentalists who maintain that information in this area is incomplete. There have been two carefully studied exposure incidents of pregnant women and animals in Poza Rico, Mexico and Terre Haute, Indiana. Although human and animal fatalities occurred, no mention was made of abortion, congenital defects, or teratogenesis. Records of the Alberta Animal Health Laboratory before, during, and after blowout episodes have not recorded any evidence of abortions or birth defects arising from exposure. A major concern in this area is the presence of carbon disulphide and carbonyl sulphide. These chemicals may be present in blowout emissions. Further investigation in this area is necessary.

Effect upon Production and Performance.

Hydrogen sulphide is characterized by rapid action, immediate detoxification and elimination from the body, and no after effects from acute exposure. Following blowout exposure, livestock producers have reported cows which do poorly and must be culled from the herd in subsequent years, lack of exercise tolerance in horses, and decreased production in dairy cows. These are empirical observations by owners. They have not been established by the scientific community. Also, no satisfactory studies have been conducted on long-term low-level exposures to refute these observations. At the present, these facts are unknown.

Trace Element Deficiencies.

Sulphide is known to interact with molybdenum and copper to form insoluble complexes and to reduce the availability of selenium from the soil, thereby creating deficiencies of these elements. In the rumen, sulphide can combine directly with copper to form insoluble copper sulphide. However, considerable amounts of dietary sulphur, sulphide, or sulphate are required to produce an observable effect. Until further research can quantitate the amount of sulphide required to produce this effect and define the soil chemistry taking place, my opinion is that the amount of sulphur deposited from the concentrations of H_2S measured during recent blowouts would be insufficient to have an effect upon availability of selenium and copper. This problem is compounded by already existing deficiencies of selenium and copper in areas which may be affected by blowouts. It has been reported that H_2S caused loss of nodulation of legumes (alfalfa). Again, this is a field observation that has not been researched.

Enzyme Studies.

The selected enzymes of superoxide dismutase, glutathione peroxidase, glucose-6-phosphate-dehydrogenase, acetylcholinesterase, and aspartate aminotransferase were measured during and after a blowout episode. Significant changes were found in these enzymes in response to exposure to blowout emissions. The biological significance of these changes is not fully understood, but is believed to represent a transient biochemical response to the emissions. The altered enzymes do not demonstrate that a detrimental effect did or did not occur.

Residues in Animal Products.

Concern has been raised regarding the use of animals in a blowout area for food and possible residues in the meat. Again, H_2S is rapidly detoxified to sulphur compounds normally found in the body and rapidly eliminated with no known residual effects. It is safe to say that under no circumstances would H_2S residues be of any concern or problem.

Psychological Reaction.

An interesting aspect of hydrogen sulphide gas exposure is the olfactory response to its offensive and irritating smell. It is well established that some people exposed to near fatal doses of hydrogen sulphide develop a neuropsychological revulsion or fear associated with the odor of the gas. There is a great variation in response to odor, and levels of hydrogen sulphide at or near the odor threshold (0.1 - 0.2 parts per million) may invoke a measurable physiological response mediated through the olfactory centers of the brain. These effects are not associated with the systemic or toxic effect of the gas. The response may be determined by individual bias, sociological or economic characteristics, or awareness of sources of environmental pollutants. The reflexive responses elicited by odor or substances include, in addition to stimulation of nasal receptors, frequency and amplitude of respiratory movements, contraction of vocal chords and bronchial musculature, change in tone of blood vessels, and change in optical chronaxy.

This neuropsychogenic reaction to odors is significant in terms of assessing the health effects of the blowout. Many of the complaints regarding the health status of humans relate to this mechanism. The ill health perceived is real, but probably not caused by direct toxic action of the gas. The human perception of discomfort is then related to animals. Possibly farm animals have a similar reflexive mechanism, but the evaluation of this response would be subjective in nature. It is not possible to measure emotional feeling, minute changes in optical reaction to light, depression, or slight nausea in animals. Conversely, these changes would be easily noticeable in humans and of primary significance in pollution episodes.

Diagnosis.

At the present time there are no specific laboratory tests that can be done to confirm or deny H_2S exposure. Diagnosis of toxicity relies upon detection of expected clinical signs and known exposure to significant levels. There is some information in the literature that indicates hydrogen sulphide can inhibit heme synthesis by inhibition of alpha aminolevulinic acid and heme synthetase. This would appear to be a good area of direction to develop various laboratory tests. Sulphhemoglobin has been postulated to be of value in H_2S poisoning. This molecule has caused considerable confusion during the years and is of no value in laboratory diagnosis in that it is not produced by H_2S inhalation.

SUMMARY

Clinical signs observed during a blowout emission, at levels which do not prompt mandatory evacuation of the area, are transitory eye irritation and lacrimation, which can be noted along with mild upper respiratory irritation. Problems of abortion, infertility, and residues in meat do not occur. Trace mineral deficiencies, decreased milk yield and weight gains, and long term debility have been reported by livestock producers. Some animals may show an unusual sensitivity and animals experiencing other diseases may be adversely affected.

There are no specific measures to be taken to protect animals other than to reduce exposure by removing them from low lying areas which may accumulate gas.

Since the purpose of this workshop is to determine future research needs and direction, I would suggest the following in this priority:

1. Determine what chemicals are present in acid gases or blowout emissions.
2. Conduct scientific studies wherein animals are exposed to real world sour gas in exposure chambers.
3. Develop diagnostic tests to define the dose response relationship to acid gases.
4. Conduct epidemiological studies:
    a. Develop base line data.
    b. Operate sentinel or experimental farms.
    c. Perform epidemiological comparisons.

References.

Spitzer, F.L., et al. The Southwest Alberta Medical Diagnostic Review: Summary, Methods and Results. McGill University, Montreal, Canada: 1986.

FIELD INVESTIGATION FINDINGS OF THE LONG TERM EFFECTS IN ALBERTA LIVESTOCK EXPOSED TO ACID FORMING EMISSIONS: A CASE STUDY REPORT

T.L. Church

Lodgepole Blowout

On October 17, 1982 there was a sour gas well blowout at Lodgepole, Alberta.[1] This blowout was out of control for 67 days and was on fire for 41 days. Hydrogen sulphide exposure in the area around Lodgepole was variable and measured 5 ppm in Drayton Valley, 14 ppm at Lodgepole and Cynthia, and over 30 ppm on four occasions in other areas.[2]

In 1985, a study was conducted to determine the long-term effects of the blowout on livestock in the exposure area.[3] Twenty-eight livestock producers were interviewed concerning their experiences. Both subjective and objective data was evaluated concerning 1700 beef cattle, 40 dairy cattle and 21 sows. No records were available on weather conditions, soil and forage, nutrient levels, disease problems, or fly and parasite problems.

Beef cattle producers had complaints about open cows, increased numbers of abortions, and increased numbers of late calves (over 14 month calving interval). Four producers complained of poor growth and milk production in replacement heifers which had been exposed to the blowout at an early age. Two herds reported abnormal breeding cycles, and abnormal hair color was reported in some herds. Most of these problems were prevalent in 1983, although the number of late calves increased from 1983 to 1985. An increased percentage of beef calves born after the blowout were small, weak, and nonaggressive. There was also a higher number of stillborn and defective calves born in 1983. Two common problems reported were deformed front legs and light weaning weights. Based on records from three farms, weaning weights were 60 to 100 pounds lighter than average. Scours was also identified as a problem on some farms.

The one dairy farmer interviewed experienced a 20% decrease in milk production for three months. The calving interval decreased from 13.9 months in 1983 to 11.8 months in 1985 and replacement heifers had lower than expected production. These heifers, however, were from an unproven sire.

A swine producer recorded an increase in abortions and deformities from 1982 to 1983. Some brood sows were culled and replacement sows which had been exposed to sour gas demonstrated abnormal cycling, poor performance, and small litters. The number of pigs/sow/year decreased from 16.8 in 1980 and 20 in 1981, to an average of 12 for 1982-1984.

Many of the problems reported by producers could be due, in part, or wholly, to factors other than sour gas. Management practices, weather, and variations in livestock may all contribute to their occurrence. There was, however, an increase in the number of complaints and/or problems immediately after the blowout, and producers closer to the blowout indicated a greater number of problems.

Case Study of Abnormalities in Cattle

Along with several other beef herds, purebred Angus cattle in this case study were exposed to emissions from the Lodgepole blowout. The owners expressed concern over many problems in their 118 cow herd following this incident. Eight problem areas were identified: average decrease of 15 pounds in birth weight; 4.6% increase in birth defects or stillborn calves; 100 pound decrease in weaning weights; hair color faded and greying; 23% increase in culling rate; 9.5% increase in abortions; decreased growth and milking ability of heifers born in 1983; and breeding problems such as abnormal cycling.

Ten neighboring herds were identified for comparison purposes. These herds consisted of purebreds and crosses from the Angus, Hereford, Charolais, Simmental, and Limousin breeds. None of the observed problems could be linked to a specific breed. Only three of the ten herds had more than two of the problems listed. These herds were the largest in the comparison group and ranged from 65 to 111 head. Cattlemen stated that some of these problems were due to age, feed availability and fly problems. Selenium deficiency was also a possible factor depending on whether or not it had been supplemented.[2] It was not possible to determine why more problems were reported from the case study herd than other comparison herds.

The owners of the case study herd complained to the Minister of Agriculture that the blowout had irreparably damaged their cattle herd and they were no longer capable of performing satisfactorily. To further investigate their complaints, six pregnant cows were purchased by Alberta Agriculture. The cows were selected by the owners as being typical of the problem and were delivered to the Veterinary Diagnostic Laboratory in Edmonton on January 20, 1986. These cows were tested for any identifiable abnormalities that could be related to the sour gas blowout using available laboratory testing procedures. Four of the cows were born on the farm and had been exposed to either one or two blowouts. The other two cows were purchased from a herd that had been downwind of a gas plant which gave off sulphur emissions, and which had also been exposed to the Lodgepole blowout.

To determine if there were any abnormalities present in the cows or their offspring, each cow was subjected to specific tests to evaluate their present condition. These tests were as follows:

1. Physical examination on arrival.
2. Parasitological screening.
3. Clinical pathology - once a week for three weeks
    a. Clinical chemistry
    b. Hematology
    c. Urine samples
4. Performance aspects.
5. Post-mortem examination.

Individual Cow Data

1. HPAF-11J

    a. Born April 7, 1977 - birth weight 73 pounds,

    b. Physical Examination 86.02.13.

    Pregnant four months, sand cracks on lateral claws of all four feet with the toes on front hooves broken off.

    Left quarter is blind and indurated.

    c. Parasitological screening.

    No endoparasites, Ectoparasites - positive for Linognathus vituli (sucking lice).

    d. Clinical pathology.

    See Table 1.

    e. Performance Aspects.

    Eight calves, all normal with average birth weights of 77 pounds born from 1979 to 1986.

    Two calves died early due to health problems:

    Calf No. 5 - Male, born Feb. 27, 1983, 79 pounds; had consistent breathing problems.

    Calf No. 7 - Female, born March 3, 1985, 43 pounds; had poor growth and died after health complications.

    f. Post-mortem Examination - March 6, 1986.

    Hooves on all four feet misshapen and the coffin bone misshapen, suggestive of an old founder lesion (laminitis).

Walled off abscess in right lung which had been present for weeks to months with little effect on the cow. This could possibly be due to aspiration. Corynebacterium pyogenes was present.

Microscopic lesions of a mild inflammatory nature were found in several organs. They are commonly found in adult cows and unlikely to have affected the performance.

Heart - found the parasite Sarcocystis.

Trachea and bronchi - lesions were chronic, mild, and active, which seems incompatible with exposure to an irritant from four years previously.

Fetus - normal.

Abundance of internal fat.

Small degree of fatty change in the liver.

2. CXO-36J

a. Born June 15, 1977.

Purchased June 15, 1981.

b. Physical examination 86.02.13.

Pregnant five months, hooves normal.

c. Parasitological screening.

Endoparasites tests were negative. Ectoparasites tests were positive for Linognathus vituli.

d. Clinical pathology. See Table 1.

e. Performance aspects.

Five calves born:

Calf No. 1 - Male, born Jan. 15, 1982, 74 pounds; sold to commercial breeder.

Calf No. 2 - Female , born March 20, 1983, 64 pounds, poor growth and sold.

Calf No. 3 - Female, born March 16, 1984, 70 pounds, retained in herd.

Calf No. 4 - Male, born May 4, 1985, 72 pounds, sold to feedlot.

Calf No. 5 - Male, born May 9, 1986, 88 pounds. Weight October 28, 1986 - 485 pounds; adjusted weaning weight - 524 pounds.

f. Post mortem examination.

Lung - Mild, chronic bronchio-interstitial inflammatory reaction atypical of normal aging process in response to repeated exposure to various antigens.

Heart - *Sarcocystis*.

3. CXO-33K

a. Born April 2, 1978. Purchased June 15, 1982.

b. Physical examination (87.02.13); pregnant 6-7 months.

c. Parasitological screening:

Endoparasites - positive for coccidia 250 oocysts/gm of feces.

Ectoparasites - positive for *Linognathus vituli*.

d. Clinical pathology. See Table 1.

e. Performance aspects:

Five Calves:

Calf No. 1 - Male, born January 30, 1982, 66 pounds; poor growth and sold.

Calf No. 2 - Female, born April 8, 1983, 67 pounds; poor growth and sold.

Calf No. 3 - Female, born February 19, 1984, 75 pounds; very good animal.

Calf No. 4 - Male, Born February 24, 1985 - 93 pounds; sold, mediocre growth.

Calf No. 5 - Male, born March 15, 1986; 83 pounds; rejected by dam, necropsied at 3 weeks, normal.

f. Post-mortem examination (June 24, 1986).

Moderate fat reserves.

Upper posterior molars worn to the gum.

Right front mammary gland shows some fibrosis.

Cysts of *Sarcocystis* present in the heart.

Mild, multifocal, nonsuppurative myocarditis possibly secondary to *Sarcocystis*.

Lateral hoof of both front feet are long and misshapen. The lateral digit of the front foot and the distal border of the third phalanx has an irregular contour. These changes are typical of laminitis.

4. AUZ-37L

a. Born March 4, 1979; purchased October 30, 1979.

b. Physical examination February 13, 1986.

Sand cracks on lateral claws of RR, LF and LR.

Hooves were elongated on the LR, both rear pasterns were dropped.

Pregnant eight months.

c. Parasitological screening:

Endoparasites - positive for coccidia 100 oocysts/gm of feces.

Ectoparasites - positive for *Linognathus vituli*.

d. Clinical pathology. See Table 1.

e. Performance aspects:

Five calves:

Calf No. 1 - Female, born March 2, 1982; 69 pounds; sold in the U.S.A.

Calf No. 2 - Stillborn, 1983.

Calf No. 3 - Male, born April 3, 1984, 61 pounds; sold to feedlot.

Calf No. 4 - Male, born February 26, 1985, 75 pounds; poor growth and sold to feedlot.

Calf No. 5 - Female, born February 13, 1986, 77 pounds; weight August 14, 475 pounds; adjusted weaning weight 514 pounds.

f. Post-mortem examination - September 14, 1986:

Hooves all four feet are excessively long; no deformities observed.

Lesions of Sarcocystis in cardiac and skeletal muscle.

Histologic findings: chronic bronchio-interstitial pneumonia typical of an infectious process or hypersensitivity reaction, and likely developed over past few weeks or months.

5. HPAF-68P

a. Born March 21, 1982, 78 pounds.

b. Physical examination February 13, 1986.

Pregnant 5-6 months.

Hooves normal.

c. Parasitological screening:

No Endoparasites.

Ectoparasites - positive for Linognathus vituli.

d. Clinical pathology, see Table 1.

e. Performance aspects:

Three calves:

Calf No. 1 - Born April 9, 1984, 35 pounds; poor calf and was sold.

Calf No. 2 - Born March 27, 1985, female, 69 pounds; poor growth possibly due to poor milk from the dam; this animal was sold.

Calf No. 3 - Fetus, necropsied as normal.

f. Post-mortem examination March 5, 1986:

Lesions were found microscopically of a mild inflammatory nature in lung and kidney which is common in adult cows.

Heart - found the parasite Sarcocystis accompanying the lesions.

Trachea and bronchi - these lesions were chronic, mild, and active, which seemed incompatible to an irritant from four years ago. These lesions may be due to an allergic reaction to inhaled dust.

Fetus normal.

Slight amount of fatty change in liver hepatocytes.

Abundance of internal fat.

6. HPAF-78P

a. Born April 4, 1982; 74 pounds.

b. Physical examination February 13, 1986.

Hooves overgrown on both hind feet.

Sand cracks on lateral claw of right front.

Broken toes on left front foot.

Pregnant - seven months.

c. Parasitological screening:

No endoparasites; ectoparasites - positive for Linognathus vituli.

d. Clinical pathology - see Table 1.

e. Performance aspects:

Three calves born:

Calf No. 1 - Female, born April 4, 1984, 58 pounds; poor growth and sold.

Calf No. 2 - Male, born April 28, 1985, 72 pounds, poor growth and sold.

Calf No. 3 - Female, born March 15, 1986, 83 pounds; weight August 14 - 430 pounds; adjusted weaning weight - 567 pounds..

f. Post-mortem examination - September 14, 1986.

Very few lesions, one small liver abscess; mammary tissue firm, long hooves.

Lesions of Sarcocystis in myocardium and skeletal muscle. No significant respiratory lesions.

Discussion

On arrival, all six cows were somewhat thin but in a normal state of health and 4 to 8 months pregnant. Three had sand cracks and broken hooves, and one had a non-functional (blind) mammary quarter.

Following a parasitological screening, all of the cows were found to be free of roundworms (*Ostertagia sp*.) and lungworm (*Cooperia sp*.) Two animals were positive for coccidia at 100 to 250 oocysts/gram of feces. *Linognathus vituli* (sucking lice) was observed in all animals.

The clinical pathology was evaluated from blood samples taken on February 6, 13, and 27, 1986. These samples were sent to the O.S. Longman Building and the Alberta Environmental Centre in Vegreville, Alberta (Table 1). Of the parameters measured, only lactate dehydrogenase differed markedly from normal values. This is indicative of cellular necrosis with the most likely source being liver disease. Selenium and Vitamin A concentrations were also marginally deficient in all six cows. Vitamin E levels were abnormally low; this was probably due to an extended storage of the samples before analysis. Other parameters which deviated slightly from normal for one or more cows were superoxide dismutase, unsaturated iron binding capacity, glutathione peroxidase, plasma acetylcholinesterase, glucose 6-phosphate dehydrogenase, creatine phosphokinase, SGOT, globulin, and total protein.

Twenty-eight calves born to these cows had an average birth weight of approximately 70 pounds. The four calves and two fetuses observed at the laboratory in Edmonton were normal in weight and appearance. Of the 23 calves born to these cows, the owner reported that 13 animals had been in poor health, or demonstrated poor growth. Seven of the 13 were born in 1983-1984 after the Lodgepole blowout.

It is difficult to objectively evaluate the poor performance of these calves because the fall weaning weights and size performance records were not available. Thus, lack of this data confounded effects that may have been due to sour gas exposure. Three calves were maintained at the laboratory until weaning age. The cows were fed good quality timothy hay while nursing the calves. The two heifer calves achieved adjusted weaning weights 5.33% and 16.2% greater than the Alberta average for Angus calves enrolled on Federal-Provincial ROP (488 lb). The bull calf had an adjusted weight 2.8% less than the Alberta average (539 lb).

No pathological lesions could be found which were strongly suggestive of known sour gas toxicosis. Three cows had misshapen hooves suggestive of laminitis and one cow had a lung abscess. This abscess would have had little effect on her performance and was probably due to foreign body aspiration. Mild, chronic inflammatory lesions were found in lungs and other organs in three of these cows. Those found in the trachea and bronchi were chronic, mild, and still active, which seems incompatible with exposure to sour gas four years ago. Some type of auto-immune reaction cannot be entirely ruled out. Sarcocystis in heart and skeletal muscles is commonly seen in cows in Alberta, and in low numbers does not affect performance.

Conclusions

After studying the data collected on these six cows, it is difficult to state that no observed pathological findings were due to a previous sour gas exposure. Physical examinations were within expected variations.

Calves born to these cows seemed to have a high chance of being in poor health or demonstrating poor growth. According to farm records, approximately 46% of the calves born to these cows were sold or died for these reasons. There was no objective information given on weaning weights. Owners' interpretations may be biased. The three calves raised at the laboratory grew at average to above average rates.

In addition, it is most difficult to discriminate between natural variability and the effects produced by sour gas. The exposure concentrations in the field were not known. Additionally, these animals were at different ages at the time of exposure. With a small sample size, it is difficult to discern any patterns in the parameters monitored. Because the cows were not randomly selected, they may not be representative of the entire herd.

Although known effects of sour gas could not be found after clinical and pathological examination of these cows, the possibility cannot be dismissed. A study involving a much larger sample size including unexposed or control herds would be required to assess the effects of sour gas emissions. Exposure to known concentrations of sulphur emissions followed by objective data collected over a number of years would compliment information obtained from field observations.

References

1. ERCB Lodgepole Inquiry Report. Inquiry Report to the Lieutenant Governor. Calgary, Alberta; Energy Resources Conservation Board (ERCB): 1984.
2. ERCB Report on the Lodgepole Blowout. ERCB Reports. Calgary: Energy Resources Conservation Board (ERCB); 1984.
3. Harris, B. Field investigation findings of the long term effects in Alberta livestock exposed to acid forming emissions: survey following the Lodgepole blowout. In Coppock RW, Lillie LE, ed. Effects of Acid Forming Emissions on Livestock: Proceedings of an International Workshop. Vegreville, Alberta: Alberta Environmental Centre. 1992.

Table 1. Haematology findings for Case Study.

	CXO-36J	CXO-33K	HPAF-78P	AUZ-37J	HPAF-11J	HPAF-68P	AVG[a] FOR ALL 6 COWS	NORMAL VALUES
RBC[1]	6.79	6.59	6.23	6.11	5.83	6.46	6.34	AEC* - 4.85-9.49 U of S**-5.0-10.0
Hgb[2]	127	129	113	115	108	117	118	AEC - 88-166 U of S-80-150
HCT[3]	.37	.37	.32	.33	.30	.34	.34	AEC - .25-.48 U of S-.24-.46
MCV[4]	54	55	51	53	52	52	53	AEC - 41-62 U of S-40-60
MCH[5]	19	20	18	19	18	18	19	AEC 1- 16-19 U of S- 11-17
MCHC[6]	345	353	352	350	358	347	351	AEC - 314-370 U of S-300-360
WBC[7]	8.0	6.2	6.4	7.9	6.4	6.4	6.9	AEC - 4.9-10.7 U of S-4.0-12.0
Neutrophils	.27	.20	.33	.53	.46	.37	.36	AEC - .11-.44 U of S-.15-.45
Band Cells[8]	.01	-	-	-	-	-	.00	AEC - 0-.02 U of S-0-.02
Lymphocytes	.58	.65	.57	.39	.43	.56	.53	AEC - .39-.69 U of S-.45-.75
Monocytes	.03	.03	.02	.02	.06	.02	.03	AEC - .01-.08 U of S-.02-.07
Eosinophils	.12	.11	.08	.07	.05	.04	.08	AEC - 0-.17 U of S-0-.02
Basophils	-	.01	-	-	-	.01	-	AEC - 0-.01 U of S-.15-.45

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[a] Average of blood values taken on Feb. 6, 13, and 27, 1986.
[1] RBC - Red Blood Cells x 10^{12} per litre
[2] Hgb - Haemoglobin - grams per litre
[3] HCT - Hematocrit - litres of red blood cells per litre of plasma
[4] MCV - Mean Corpuscular Volume - femtolitres (10^{-15} L)
[5] MCH - Mean Corpuscular Haemoglobin - picograms (10^{-12} g)
[6] MCHC- Mean Corpuscular Haemoglobin Concentration - grams per litre
[7] WBC - White Blood Cells x 10^{9} per litre
[8] Band- Immature neutrophils

Table 2. Clinical chemistry for the Case Study. Page 1 of 4

	CXO-36J	CXO-33K	HPAF-78P	AUZ-37J	HPAF-11J	HPAF-68P	AVG[a] FOR ALL 6 COWS	NORMAL VALUES
Glucose[1] (mmol/L)	4.53	4.01	4.12	4.1	4.25	4.26	4.21	AEC* - 3.0-5.6 U of S**-1.9-3.1
Total Protein[2] g/L	84.55	74.2	75.8	77.3	84.7	80.33	79.5	AEC - 63-81 U of S-57-81
Albumin g/L	39.2	37	39.8	38.7	33.3	39.2	37.9	AEC - 29-44 U of S-21-36
Globulin g/L	43.7	35.7	34	37	49.3	40.7	40	AEC - 34-37 U of S-36-44
Albumin/ Globulin ratio	.87	.99	1.12	1.00	.65	.95	.93	AEC - --- U of S ---
Cholesterol mmol/L	2.50	2.61	2.46	2.29	2.03	2.47	2.39	AEC - 2.19-5.58 U of S-1.00-4.60
Triglycerides mmol/L	.30	.16	.22	.17	.15	.32	.22	AEC - .07-.41 U of S-.17-.51
Iron[3] mol/L	19.7	18.3	37.5	13	30	33	25.3	AEC - 22-37 U of S-14.5

[a] Average of blood values taken on Feb. 6, 13, and 27, 1986.
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**Western College of Veterinary Medicine

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[3] mol/L = micromoles per litre
[4] Unsaturated Iron Binding Capacity in µmol/L
[5] ppb = parts per billion in serum; 50 to 70 ppb is marginally deficient and less than 50 ppb is deficient
[6] Alk. Phos. = Alkaline Phosphatase - SI units per litre
[7] LDH = Lactate Dehydrogenase - SI units per litre
[8] CPK = Creatine Phosphokinase - SI units per litre
[9] AST = Aspartate Aminotransferase or SGOT - serum glutamic oxaloacetic transaminase - SI units per litre
[10] ALT = Alanine Aminotransferase or SGPT - serum glutamic pyruvate transaminase - SI units per litre
[11] SOD - Superoxide Dismutase - units per millilitre of packed erythrocytes
[12] GSHPx = Glutathione Peroxidase - units per millilitre of packed erythrocytes
[13] G6PD = Glucose 6-Phosphate Dehydrogenase - units per millilitre of packed erythrocytes
[14] AChE = Acetylcholinesterase - units per millilitre of packed erythrocytes
[15] PAChE = Plasma Acetylcholinesterase - units per millilitre of packed erythrocytes
[16] GGT = Gamma Glutamyltransferase - SI units per litre

Table 2. Clinical chemistry for the Case Study (continued). Page 2 of 4

	CXO-36J	CXO-33K	HPAF-78P	AUZ-37J	HPAF-11J	HPAF-68P	AVG[a] FOR ALL 6 COWS	NORMAL VALUES
UIBC[4] µmol/L	48	33.7	32.5	35.3	33.3	36	36.5	AEC - --- U of S-44.8-62.7
Selenium[5] ppb	60	57	58.7	56.7	47.7	69.3	58.23	AEC - --- U of S----
Copper ppm	.83	.64	.73	.64	.94	.70	.74	AEC - --- U of S-.5
Zinc ppm	.83	.90	.86	.67	.87	.84	.83	AEC - --- U of S-.8-2.5
Calcium mmol/L	2.36	2.34	2.40	2.40	2.31	2.47	2.38	AEC - 1.99-2.85 U of S-2.0-2.62
Phosphorus mmol/L	.99	1.14	1.11	1.1	1.26	1.2	1.13	AEC - .96-2.72 U of S-1.3-2.25
Magnesium mmol/L	1.02	1.06	1.06	1.02	.89	1.22	1.00	AEC - .49-1.15 U of S-.50-1.45
Sodium mmol/L	143	143	140	146	138	143	142	AEC - 132-150 U of S - ---
Potassium mmol/L	4.5	4.1	4.2	4.2	3.6	4.3	4.2	AEC 1- 3.8-5.4 U of S -3.9-5.8

[a] Average of blood values taken on Feb. 6, 13, and 27, 1986.
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Table 2. Clinical chemistry for the Case Study (Continued). Page 3 of 4

	CXO-36J	CXO-33K	HPAF-78P	AUZ-37J	HPAF-11J	HPAF-68P	AVG[a] FOR ALL 6 COWS	NORMAL VALUES
Chloride mmol/L	105	106	101	107	104	105	105	AEC - 91-106 U of S-95-110
Total Bilirubin mol/L	5.98	6.15	5.68	6.26	3.88	5.25	5.53	AEC - 0-6 U of S-0-32
Direct Bilirubin mol/L	1.0	1.3	.5	1.3	.33	1.0	1.0	AEC - 0-2 U of S-0-7
Blood Urea Nitrogen m mol/l	4.55	4.57	4.42	5.18	3.25	5.2	4.5	AEC - 3.7-9.5 U of S-2.0-9.5
Creatine mol/L	140.0	165.4	149.8	129.9	93.4	142.9	138.0	AEC - 110-169 U of S- 90-240
Uric Acid mol/L	41.9	44.6	40.0	34.3	30.8	39.7	38.6	AEC - --- U of S-0-119
Alk.Phos.[6] U/L	37.5	50.2	136.2	105.3	73.7	188	98.5	AEC - 38-209 U of S-35-350
LDH[7] U/L	772	750	690	634	658	1132	772	AEC - --- U of S-500
CPK[8] U/L	105.5	99	87.6	77.3	70.8	287.7	121	AEC - 94-205 U of S-12-48

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[16] GGT = Gamma Glutamyltransferase - SI units per litre

Table 2. Clinical chemistry for the Case Study (Continued). Page 4 of 4

	CXO-36J	CXO-33K	HPAF-78P	AUZ-37J	HPAF-11J	HPAF-68P	AVG[a] FOR ALL 6 COWS	NORMAL VALUES
AST[9] U/L	62.8	65.2	61.8	68.8	49	93	67	AEC - 60-107 U of S ---
ALT[10] U/L	21.3	26.0	25.0	117.7	18.7	24.3	22.2	AEC - 14-31 U of S ---
SOD[11] U/mlpe	297	256.4	297	264.7	308	199	283.4	AEC - 312-352 U of S ---
GSHPx[12] U/mlpe	19.5	18.3	14.3	28.1	25.1	21.2	21.2	AEC - 26.82-29.88 U of S ---
G6PD[13] U/mlpe	.78	1.24	.73	1.25	.82	.92	.96	AEC - 1.02-1.18 U of S ---
AChE[14] U/mlpe	5.12	5.71	5.30	5.04	4.46	5.17	5.13	AEC - 3.91-5.00 U of S ---
PAChE[15] U/mlpe	89.8	174.3	97.3	104.7	65.9	294.1	131.7	AEC - 60-160 U of S ---
GGT[16] U/mlpe	20.3	12.3	16	16.3	17.3	15	16	AEC - 4-28 U of S ---
Vit. A ppm	12.6	12.7	12.6	10.0	6.7	12.8	11.2	AEC - --- U of S ---
Vit. E ppm	5	9.4	5.0	13	5.4	8.0	7.6	AEC - --- U of S ---

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FIELD INVESTIGATION FINDING OF LONG TERM EFFECTS IN ALBERTA LIVESTOCK EXPOSED TO AID FORMING EMISSIONS: SURVEY FOLLOWING THE LODGEPOLE BLOWOUT

Brian Harris

BACKGROUND

On October 17, 1982, the Amoco Dome Brazeau River 13-12-48- 12 (13-12 well) oil well, located 20 km west of Lodgepole, was being drilled when it blew out of control. There were daily emissions into the atmosphere of 150 to 450 tonnes of sulphur, and 300 to 1100 cubic metres of condensate. For the 26 days the well was not on fire, the condensate fell on the area immediately surrounding the well site, and had an impact that was initially similar to an oil spill. During the 41 days the well was on fire, the sour gas and condensate underwent combustion in the extremely intense fire, and the hydrogen sulphide (H_2S) and other sulphur-containing constituents were converted to sulphur dioxide. Sulphur emitted from the well, primarily in a gaseous form, was eventually deposited in low concentrations over a large area.

While the well was not on fire, H_2S and other compounds were deposited throughout the area, depending on wind and atmospheric conditions. Concentrations of 14 ppm and higher of H_2S were recorded at Lodgepole and Cynthia. The highest concentration recorded at Drayton Valley was 5 ppm. Recordings varied up to a peak of 30 ppm on one occasion and beyond 30 ppm on four occasions away from residences. The H_2S standard which was applied during the blowout suggested residents evacuate the area if concentrations exceeded 5 ppm for 6 hours or 10 ppm for 1 hour. Evacuation was mandatory if concentration exceeded 20 ppm.

Many of the 30 local area residents noted problems with their farm animals during the blowout period. They stated that these animals suffered from runny eyes and noses, coughing and decreased feed intake. The claim that air pollutants caused spontaneous abortions in livestock and other animals was made by several farm witnesses. However, there is no information available at present which could confirm this claim.

Staff of the Alberta Environmental Centre attempted to determine the effects of the emissions on certain enzymes of cattle. Blood samples were taken from cattle within ten herds in the affected area during the blowout and subsequent to the capping of the well, and also from two control herds in the Vegreville area. In all cases, however, the change in enzyme activities appeared to be transient and reversible. The investigators advised that these results are highly experimental in nature and must be interpreted with considerable caution, particularly when assessing suspected clinical disease in the animals. At present, the importance of these results is not known.

There were effects during the blowout on personal property; some tangible ones were paint that was damaged and galvanized metal that was corroded; other problems were in the form of nuisance effects, that is, odors and irritation of the nose and throat. Effects on livestock, in particular, were observed during the blowout phase, but severe short-term or long-term effects are difficult to prove. Because of these concerns, the ERCB inquiry into the effects of the Lodgepole blowout recommended that "Alberta Agriculture should consider conducting an ongoing examination of livestock in the general blowout area to determine if effects of long-term exposure to sour gas can be found". This study was undertaken to evaluate opinions and attitudes of livestock producers about the long-term effects of the Lodgepole blowout.

METHOD

In May, 1985, contact was made with veterinarians Drs. Karen Josephson, John Round and T. Lookmanjee, and the District Agriculturist Doug Walkey. The problem was discussed, and a list of livestock producers who had reported problems during the blowout and had reasonable records, were selected. Initial contact was made with several of these producers to define the areas of concern. A worksheet was then developed to aid in the collection of data. The major areas of concern were: reduced growth in young stock following the blowout; abortions, and abnormal births in the following calving season; breeding problems; reduced growth in calves born the following calving season; reduced growth and performance of replacement heifers which were exposed to the blowout as calves, and heifers kept from the calves born following the blowout; and fading of hair color. It must be recognized that all these factors are influenced by individual management, weather, and natural variability within the cattle population.

The study centered around the Violet Grove area, as this was the closest populated area to the blowout, and the ERCB established it to be in the centre of the measurable sulphur deposition area. Other producers throughout the Drayton Valley area who had records were also interviewed to attempt to determine the extent of the problems.

The locations of all the people interviewed are identified (Table 1). The information recorded was based on producers' records, auction sale tickets, sales receipts, and memory. These observations were compiled as accurately as possible. A number of livestock producers had kept good records relating to livestock numbers in the herd and to the problems which have occurred over the years. Other producers did not have detailed records, but expressed in subjective terms how the stock performed as compared to their consideration of the average. Actual figures were recorded where they were available. In total, 28 livestock producers were interviewed. Their observations represented information on over 1,700 head of beef cows, 40 dairy cows and 21 sows.

Other information on weather conditions, soil and forage, nutrient levels, disease problems, fly and parasite problems was not available; but this could explain some of the problems which occurred.

RESULTS AND DISCUSSION

The effect of the blowout is difficult to define as it is masked by the normal variables of livestock production. There appear to be a number of inconsistencies which are difficult to explain. For example, a number of the problems which were observed could be explained by trace mineral deficiencies. However, producers on neighbouring farms with similar livestock did not have problems and were not supplementing diets with selenium or trace minerals. Certainly, the exposure concentrations of sour gas appeared to have been variable through the community. As the plume moved through the area, based on effects in livestock, the concentrations of sour gas were apparently higher in low areas. This was an inconsistent observation, as not all low areas were affected. Management practices varied from farm to farm, but again, some good managers had problems while others did not. The producers who were closest to the blowout reported the most problems.

The data collected is a subjective evaluation of the problem based on a producer's individual records. There are no baselines or controls to evaluate whether these problems would have occurred had the blowout not happened. Different producers expressed a range of concerns (Table 1).

None of the producers expressing concern over birth weight had recorded birth weights. Nonetheless, their opinion was that calves were small, weak, lacked aggression and were more susceptible to diseases. The concern with stillborn and defective calves appeared to have been highest in 1983. Most of the producers noted that uterine inertia of the dams and deformed front feet of the calves were significant problems. Scours and problem calves, described as having swollen ankles and runny eyes, were a concern to a few producers in most years. Several producers had severe scour problems one year and subsequently went on a vaccination program the next year. Vaccination alleviated the scour problems. In one herd of 90 cows there were 5 calves with swollen joints in 1983.

Poor growth was reported once in 1982, six times in 1983 and once in 1984. Records were available on three farms to compare each year's performance. Following the blowout, calf weaning weights appeared to be 60-100 lbs lighter than normal. One producer was of the opinion that low average weight was due to an increase in the number of small unthrifty calves. Problems with open cows were of concern in 1983 and 1984. Some of these cows were reported to have aborted the previous winter. In one herd of approximately 100 cows, seven cows were dry in the spring of 1983 and were still open in the fall. Abortion was a concern only during the winter of 1982-83; there were no concerns in 1984 or 1985.

The concern over late calves increased in the years 1983, 1984 and 1985. This would have been a greater concern since possibly other problems decreased, or it may be a carryover of a reproductive upset. Those expressing concern had over 10% late calves and these were from cows with a calving interval of over 14 months. Cows which were consistently late calvers were not included. Poor growth in replacement heifers, and poor performance of these heifers, which included milk production and udder development, were a concern of four producers. On visual examination, their heifers appeared to be smaller, finer boned, and in poorer body conditions than the balance of the herd. In at least one case, management practices accounted for some of the difference, as the heifers calved a month earlier than the cows, and were on a different feeding program. Abnormal hair color and blotching were noted by four producers during 1983. Three of these producers were close to the blowout. No abnormalities were noted in subsequent years. Abnormal breeding cycles were noticed in several cows in two herds. These cows had cycled, were bred and continued to cycle and then calve from the first service.

This description gives an overview of the livestock concerns which were expressed. A number of producers were also concerned with the amount of "winter kill" of legumes experienced after the blowout; however, weather conditions were a factor as winter kill was a problem in other areas of the province.

Dairy Production

The one dairy producer in the area had only been in production for one year before the blowout occurred. This dairy is located on the Pembina River downstream from the blowout, but was out of the sulphur deposition area. Following the blowout, milk production dropped approximately 20% for three months. Cows, which freshened after the well was capped, calved normally and produced up to expectation. However, a number of breeding problems occurred over the following year. Dairy Herd Improvement (DHI) records showed the calving interval was up to 13.9 months during 1983, but later improved to 11.8. Replacement heifers, which were young calves during the blowout, did not develop into good quality cows. It is also possible that this problem may have been genetic as these heifers were from an unproven sire. This producer experienced some feed and trace mineral problems, but since much of their feed was purchased out of the area, it is unlikely that the blowout had any affect on the problem. In general, this producer feels this herd has returned to normal.

Swine Production

There were only two relatively small swine operations in the area. In both of these, there were a number of abortions and deformed pigs in 1982-83 resulting in considerable culling of brood sows. Young stock, which had been exposed to the blowout and kept for breeding, had poor performance, abnormal cycling, and those that did conceive had small litters. Sows which were bred at the time of the blowout had small litters and deformed pigs. Subsequent litters from these sows improved. One producer reported pigs per sow/year as 16.8 in 1980, 20 in 1981, 13 in 1982, 12 in 1983, 12 in 1984 and 8.2 for half a year in 1985. It appears performance improved once the affected sows were culled.

SUMMARY

A study, conducted in June of 1985 to evaluate the long term effects of the Lodgepole blowout, was mainly a subjective evaluation of the concerns expressed by livestock producers based on their records and opinions about the problems which occurred during and after the blowout. Twenty-five beef cow-calf producers were interviewed. Two swine and one dairy producer (the only dairy and swine operators in the area) were also interviewed for the study.

The cow-calf producers were concentrated in the Violet Grove area since it was the nearest area populated with livestock in the sulphur deposition zone as outlined by the ERCB reports. Because there was no reference data or herds with complete records within the area, it was difficult to establish whether the problems may have been caused by herd management, weather, or by complications from the blowout.

To evaluate the problem, a worksheet was developed to establish cow herd performance for the years 1980-1985. Areas of concern included: number of calves born alive; stillborns and defective calves; scouring problems; and calf growth through the following year. In the cow herd, breeding performance was evaluated by attempting to tabulate the number of dry cows or open cows and examining the number of late calves which occurred in the herds under study. The problems which cow-calf producers identified were not consistent throughout the group. For example, one producer may have been of the opinion that growth rate was the major concern within his herd, and that breeding was not a problem. Another producer may have had the opinion that breeding and late calves were more of a concern especially during the years 1983 and 1984.

In an attempt to avoid bias in the evaluation of potential problems, all of the major producers within the Violet Grove area were contacted, as well as selected individual producers throughout the Drayton Valley area. Several producers had good records of their individual herd performance. However, there were no records of other variables that could have changed during the study period. These included weather conditions, fly problems, feed analysis and management changes.

When the concerns and problems encountered were tabulated, it appeared there were more problems identified during 1983 and the period following the blowout. Most of the problems have since subsided, although there still are some concerns about the performance of replacement heifers that were exposed as calves during the blowout. These heifers do not appear to have grown and developed as well as producers expected. There is some concern by several producers that these heifers are not milking as well as they should be.

In the hog operations, there appeared to be a considerable number of problems that occurred during and immediately following the blowout. Performance, evaluated as number of pigs/sow/year, definitely decreased for the two years following the blowout. Some of the gilts that were kept during that period of time had to be culled because of low performance. There were no checks and controls involved in this, and producer prejudice certainly is a factor.

In general, most livestock producers felt that there were few long term effects on the mature livestock within the area. The majority of the problem animals were culled and herd performance seems to have returned to the levels prior to the blowout.

On several farms, management practices were changed to include trace mineral supplementation with copper, zinc and selenium to help overcome the problems of weak calves. Growth rates in young stock appear to be back to normal. There are some producers who still have concerns about the development of the replacement stock which was affected by the blowout. "Winter kill" in legumes has been a problem, however, weather conditions in many areas of the province have been unfavourable for overwintering of legumes.

This report is subjective in nature since there is no concrete evidence to support many of the problems described or baseline studies to work from. In the future it would be advisable to set up a monitoring program to record livestock weight gain, birth weight, abnormalities, breeding problems, feed consumption, disease problems and necropsies of all deaths which occur. This program should be set-up immediately following the problem so that the effects can be monitored, and reliable, unbiased data can be compiled. Baseline studies of soil and forage nutrients, including trace minerals, in areas where blowouts are likely to occur would be of great value if another blowout should occur.

CONCLUSION

Most of the livestock problems which occurred following the blowout appear to have been alleviated. On several farms, management practices were changed to include trace mineral supplementation, and increased amounts of selenium were added to help overcome the problems. Growth rates in young stock appear to be back to normal. There are still concerns about the development of replacement cattle which were affected by the blowout. Mature cows do not appear to be having problems in the majority of herds. "Winter kill" in legumes has been a problem. However, weather conditions have not been ideal for overwintering alfalfa, and "winter kill" of legumes has been a problem in many areas of the province.

This report is mainly subjective in nature since there is no concrete evidence to support many of the problems described, nor baseline studies to work from. In future, it would be advisable to set up a monitoring program to record livestock weight gains, birth weights, abnormalities, breeding problems, feed consumption, disease problems, and autopsies of all deaths which occur. This program should be set up as soon as the problem occurs so that many of the effects can be monitored and controlled, and reliable data can be compiled. Baseline studies of soils and forages in areas where problems are likely to occur would be of great value if a subsequent blowout problem did occur.

Table 1. Summary of Cow-Calf Producer Concerns Following the Lodgepole Blowout.

	Year					
Area of Concern	80	81	82	83	84	85
Low Birth Weight	0	0	0	3	0	1
Stillborn or Defective	0	1	2	7	2	2
Scours and Problem Calves	0	1	1	3	1	0
Poor Growth	0	0	1	6	1	0
Open or Dry Cows	0	0	0	3	2	0
Abortions	0	0	4	0	0	0
Late Calves	0	0	0	3	6	4
Poor Growth in Replacement Heifers	0	0	0	0	2	4
Abnormal Hair	0	0	0	4	0	0
Abnormal Breeding	0	0	0	0	2	1
TOTAL (Year)	0	2	8	29	16	12

INVESTIGATING ANIMAL HEALTH EFFECTS OF SOUR GAS ACID FORMING EMISSIONS

W.C. Edwards

Sour gas is a complex mixture of aliphatic and aromatic hydrocarbons, hydrogen sulphide, and other volatile sulphur containing compounds. The volatile sulphur compounds are predominately hydrogen sulphide but may include carbonyl sulphide, carbon disulphide and mercaptans (NRC, 1986). Many states allow petroleum and natural gas processes to remove hydrogen sulphide from their emissions by scrubbing or oxidizing it to sulphur dioxide in a system that ensures complete combustion, providing that the exhaust gas contains no more than 100 pounds per hour (45.5 kg/h) of sulphur dioxide (OCC, 1986). The oxidation products of hydrogen sulphide combustion are themselves very irritating and, therefore, must meet emission standards. Because it is generally found in higher concentrations and is considered to be more acutely toxic than the other volatile sulphur compounds, hydrogen sulphide is given primary attention in sour gas well blowouts (NRC, 1986). Hydrogen sulphide has also been more extensively studied than the other sour gas constituents; and since it is subject to workplace standards, and federal and state laws, it is more frequently monitored in many industries.

Many oil producing states have guidelines for emergency field situations including sour gas well blowouts (RCT, 1985; OCC, 1983).

There are also guidelines for safe drilling operations in hydrogen sulphide environments. The general guidelines address the following:

1. Location requirements and avenues of evacuation.
2. Blowout prevention equipment, choke manifold and discharge (flare) lines as recommended by the American Petroleum Institute.
3. Monitoring equipment and alarm systems.
4. Personal protective equipment, including certified breathing apparatus.
5. Comprehensive-safety-standards training programs for all personnel involved in operations.
6. Written evacuation procedures pertinent to the location.
7. Contingency plan for firing of the well when there is no hope of controlling the blowout, or when human life and property are endangered.

Because of the great risk involved, emergency evacuation procedures and subsequent mobile monitoring must give priority to human health and safety. Consequently, animals confined in the radius of exposure are often not observed until re-entry is allowed, at which time ambient concentrations should be below the permissible exposure limits. In both the United States and Canada there are few documented cases of acute deaths in animals resulting from fatal concentrations of sour gas. There are, however, numerous cases of suspected economic losses resulting in civil lawsuits. Many of these cases are never adequately resolved for a variety of reasons. Some of the reasons include lack of monitoring data confirming ambient hydrogen sulphide levels, inadequate or insufficient overall data to meet the scientific and legal scrutiny needed to render an opinion based on reasonable medical certainty of a cause and effect relationship.

Before outlining the guidelines for field investigations of animals exposed to sour gas and acid forming emissions, it is appropriate to review the general hazards and characteristics of hydrogen sulphide (NRC, 1986). The principal hazard of hydrogen sulphide is death by inhalation. Detection of hydrogen sulphide by smell is considered highly dangerous because the olfactory senses are rapidly paralyzed by the gas. Hydrogen sulphide is extremely toxic, heavier than air (specific gravity 1.189), soluble in water and liquid hydrocarbons, flammable, and explosive. It is colorless and transparent, clings to the ground, and tends to accumulate in low places. Hydrogen sulphide is corrosive to all metals of the electrochemical series. The permissible exposure limit, as found in General Industry Standards for Toxic and Hazardous Substances, 29CFR1910, Subpart 2, as of March 11, 1984, was 20 ppm (ceiling) and 50 ppm (10 min. peak). Levels of 100 ppm are very irritating to the ocular and respiratory systems. Levels of 200 ppm rapidly kill the sense of smell, and levels of 500 ppm will cause dizziness and respiratory arrest within a few minutes. The immediate danger to health or life (IDHL) level is 300 ppm (NIOSH, 1986). Therefore, knowing the limitations and capabilities of detection devices can save lives. When testing, one should always be prepared for a high concentration of the gas.

Following a blowout incident and evacuation of the local population, the operating company should notify all appropriate federal, state and local authorities. Re-entry to evacuate or examine livestock and domestic animals is generally not warranted. Under special circumstances veterinarians specially trained in emergency procedures, including the use of certified breathing apparatuses and mobile monitoring equipment, might enter restricted areas with federal or state authorization to examine animals. However, in most instances, animals will not be examined and evaluated until the blowout is under control and re-entry is authorized.

General guidelines (AEC, 1986) for field investigations into the effects of sour gas and acid emissions on livestock should include the following:

1. A detailed map indicating the types and number of animals relative to the well site.
2. Data to calculate the 100 ppm and 500 ppm radius of exposure, as per the Pasquill-Gifford equation, or other methods (OCC, 1983).
3. Weather data, which should include wind direction and velocity, humidity and ambient temperature. This data is often available from local airports or the nearest National

Weather Service facility. If available, mobile weather stations should also be used.

4. A veterinarian's examination of animals suspected of being exposed to sour gas or acid forming emissions. Blood and serum samples should be collected for hematologic and serum chemistry studies.
5. Close monitoring of animals for signs of ocular and respiratory tract irritation. The reproductive status of the animals should be determined. Animals should also be monitored for feed intake and performance.

While not all investigators accept chronic hydrogen sulphide poisoning as a condition that is distinct from acute or subacute poisoning, it may be appropriate to apply the term to those cases where there is a prolonged display of clinical signs resulting from intermittent exposure to low or intermediate concentrations (50 to 100 ppm) of hydrogen sulphide. The threshold for serious eye injury (gas eye) is in the 50 to 100 ppm range (NRC, 1986; NIOSH, 1986). Chronic long term effects in humans have been lingering and largely subjective manifestations of illness including neurological, cardiovascular, pulmonary and ocular disabilities.

Animals may be more susceptible to hydrogen sulphide exposure because they graze with their heads at ground level, where the concentration of hydrogen sulphide may be the greatest. Animals, whether in confinement or not, may not be able to escape from the area as humans can. And, the potential for secondary bacterial infections is greater in the animal population following irritation to the eyes or lungs than in humans. Hydrogen sulphide at low levels for short periods of time may act as an irritant and as an initiator of bacterial infection (Hayes, et al., 1965).

We have been involved in claims of spontaneous abortions following exposure to hydrogen sulphide. While there is a paucity of information available to support or refute such claims, one can postulate that levels sufficient to cause respiratory dysfunction may cause fetal hypoxia sufficient to cause fetal death and subsequent abortion.

The role of the Animal Disease Diagnostic Laboratory in the case of suspected animal exposure to hydrogen sulphide and acid forming emissions is to assist the veterinarian in the field in making a diagnosis. Complete postmortem evaluations including histopathology, bacteriology, virology and toxicology are essential in cases which may be litigated. Field investigations are needed to evaluate overall nutrition and management practices, which may be contributing factors.

A review of a case history of a sour gas well blowout in the United States will point out that our problems in dealing with acid forming emissions are similar to those experienced in Canada.

CASE HISTORY

The Ross No. 2 gas well blowout occurred July 15, 1985 in Rankin County, Mississippi. The initial gas flow was estimated at 40 million cubic feet per day at pressure of 19,000 psi and hydrogen sulphide content was 35%. Because of the high hydrogen sulphide concentrations, the well was fired, and later capped on September 25, 1985, seventy-two days later. At peak discharge, the 500 ppm radius of exposure, utilizing the Pasquill-Gifford equation, was 18,104 feet, or approximately 3.5 miles.

Pasquill-Gifford Equation

$X_{500} = [(0.4546)\ (MF)(Q)]^{0.6258}$

and

$Q = 40 \times 10^{6}$

$MF = 0.35$

$X_{500} = 18{,}104$ feet

X_{500} = Radius of exposure (ROE) in feet

Q = Discharge in cubic feet per day

MF = Mole fraction hydrogen sulphide

Because of the hydrogen sulphide concentrations and the proximity to the well site, residents in the vicinity of Johns, Mississippi were evacuated.

A purebred red and gray Brahman cattle embryo transplant operation was located a little over one-half mile from the well. After the well was fired, the cattle were examined by a local veterinarian on July 20, 1985. Of the approximately 150 head of cows and calves, all had eye irritations, epiphora, nasal discharge and coughing. The rectal temperatures were in the normal range. On August 25, 1985, most of the exposed animals showed clinical signs of a severe dry hacking cough, epiphora, dry rales over the thoracic inlet, and a bronchial "popping" sound over the lateral thorax. Twenty-four animals were examined on August 27, 1985. All 24 had epiphora and evidence of eye irritation. Fifteen of the 24 had abnormal lung and tracheal sounds. An additional 25 animals were examined August 28, 1985. All 25 had abnormal respiratory sounds and eye irritation. Cultures for *Pasteurella* spp, and serological tests for IBR and PI_3 did not indicate any infection. Of 55 animals showing signs of respiratory distress and eye irritation in August of 1985, 15 were still clinically ill in May of 1986. The attending veterinarian noted that these animals exhibited labored breathing, periodic chronic coughs and exercise intolerance in that the respiratory distress was made worse with mild exertion.

Blood samples collected from 124 animals on August 28, 1985 were analyzed and the data summarized (Table 1). While several of these parameters appeared elevated, the interpretation was inconclusive in that the serum may have been left on the red blood cells too long. The anion gap was suggestive of a respiratory acidosis.

The legal liabilities on this case were settled in October of 1986. Because of a "hush" included in the settlement, additional relevant data may not be released regarding the total economic impact of the blowout. Complete weather data, topography maps and air monitoring data were not available to construct a dispersion model.

In conclusion, livestock problems associated with acid forming emissions observed in the United States are similar, if not identical, to those observed in Alberta.

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TABLE 1. Clinical chemistries on 124 blood samples collected August 28, 1985.

	AVG.	S.D.
Glucose	56.2	32.4
SGPT	38.0	12.0
SGOT	93.0	28.0
GGTP	27.0	13.0
LDH	1169.0	207
SAP	183.0	177.0
Cholesterol	155.0	45.0
CO_2	26.0	3.2
Anion gap	21.0	5.0
Potassium	4.96	0.76

FINDINGS OF A RETROSPECTIVE SURVEY CONDUCTED AFTER THE LODGEPOLE SOUR GAS WELL BLOWOUT TO DETERMINE IF THE NATURAL OCCURRENCE OF BOVINE ABORTIONS AND FETAL ANOMALIES INCREASED

G. G. Klavano and R. G. Christian

INTRODUCTION

The Lodgepole (Amoco - Dome Brazeau River 13-12-48-12) sour gas well blew out of control from 14:30 h on October 17, 1982 to 14:00 h on December 23, 1982. At 14:07 h on November 1, 1982 the well was ignited and burned until November 17, 1982. The well again ignited at 12:53 h on November 25, 1982 and burned until it was extinguished during the capping process, which took place in the December 4 to December 23, 1982 interval (ERCB, 1984).

The rate flow from the Lodgepole well was estimated to be 2.8×10^6 to 4.2×10^6 m^3 per day or greater (ERCB, 1984b). Emitted gas was estimated to contain at least 30% hydrogen sulphide or 300,000 ppm.

This retrospective survey was conducted after the Lodgepole sour gas well blowout to determine if the blowout incident changed the number and type of bovine abortions and abnormal bovine feti submitted to the diagnostic laboratory from the blowout area.

MATERIALS AND METHODS

The records of the total number of bovine feti submitted to the Animal Health Division Laboratory in Edmonton were compared between three areas to determine if there was a significant difference between the areas closer to the well site and the larger total area.

Area 1 is approximately 141,000 km^2 and contains a variety of geographical features, including mountains in the west to prairies in the southeast. The soil type varies from brown in the southeast, to black in the central part and gray-wooded towards the west. There are considerable areas of muskeg and forest located within this region; however, it is primarily rolling park land. In 1982, the area contained approximately 700,000 beef and 105,000 dairy cows. Crops grown included barley, wheat, canola, oats, and forages.

Area 2 is approximately 27,000 km^2 and varies from park land in the east to foothills and mountains in the west. The soil varies from black to gray-wooded. There are large areas of forest in the western part of this area. In 1982, it contained approximately 270,000 beef and 58,000 dairy cows, with the main livestock populations located in the eastern part of the area.

Area 3 is approximately 5,700 km^2 and contains primarily park land to the east and forest to the west. The soil type is primarily gray-wooded. The location of the well blowout is in the western part of this area. Data from 1982 indicated that the area contained 20,800 beef and 900 dairy cows. Crops produced included barley, canola, wheat, oats, and forages. Livestock production was primarily located near the northern and eastern boundaries of the area. No livestock was located to the west and south of the well site.

Information on diseases and conditions diagnosed in aborted feti and newborn calves was collected and collated in order to compare disease occurrence in the three areas. Information was also collected from prior years and subsequent years for comparison purposes.

RESULTS

This survey demonstrated that the total number of submissions to the Edmonton Animal Health Division Laboratory from Area 1 decreased moderately during the winter of the blowout (1982-83). Numbers increased during the following 2 winters (Table 1). The number of submissions from Area 2 increased moderately during the winter of the blowout, decreased a year later and then returned to a level similar to the years before the blowout.

The numbers of submissions from Area 3 moderately increased during the winter of the blowout and continued for the next 2 winters.

Tables 2, 3 and 4 list all diagnoses made in Areas 3, 2 and 1 for 2 years prior to the blowout, the year of the blowout, and 2 years following. Congenital defects for all 3 areas are listed in Table 5. During the winter of the blowout there was an increase in the diagnoses of dystocia, which may have occurred because of an increased awareness by producers to check on losses. In addition, three cases of abortion due to cows consuming pine tree needles occurred, unrelated to the blowout.

An increase in the multiple metabolic and other congenital defects in Area 1 the winter following the blowout was a result of 12 submissions from one herd where the calves were affected by a dominant hereditary condition of brachynathism inferior, intrauterine growth retardation, and oxaluria. An increase in musculoskeletal defects in Area 3 in 1984/85 was due to a hereditary congenital defect in 3 calves from one herd.

DISCUSSION

Laboratory submissions, while not a random, statistically valid sampling of the occurrence of abortions and congenital defects, can provide an indication of changes or trends that have occurred. However, in the survey described, no changes or trends could be ascribed to the well blowout.

References

Energy Resources Conservation Board (ERCB). Report of the Lodgepole Blowout Inquiry Panel: Phase 1 Report. Calgary, Alberta: ERCB, December 1984a.

Energy Resources Conservation Board (ERCB). Addendum to the Phase 1 Report. Calgary, Alberta: ERCB, December, 1984.

TABLE 1. Bovine Fetal Submissions

	Total Feti Submitted		
Date	Area No. 1	Area No. 2	Area No. 3
October 1979 - April 1980	575	103	18
October 1980 - April 1981	583	104	18
October 1981 - April 1982	485	97	29
October 1982 - April 1983	517	129	39
October 1983 - April 1984	815	63	40
October 1984 - April 1985	859	111	42

Description of Areas:

Area No. 1:	Area from Saskatchewan border to B.C. border and from Red Deer to Valleyview.
Area No. 2:	Edmonton south to Red Deer, west to Rocky Mountain House, north to Highway 16, and east to Edmonton.
Area No. 3:	Wabamun south to Buck Lake, west for 60 km, north to Carrot Creek, east to Wabamun.

TABLE 2. Abortions and Birth Defects in Area 3.

Observation	Year 1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
Bacterial Abortion						
Bacillis	0	0	0	0	0	1
Coliform	0	1	1	0	1	0
Corynebacterium	3	0	1	0	0	2
Enterobacter	1	0	0	0	0	0
Listeria	1	1	1	0	0	0
Mixed	0	0	0	0	0	0
Pseudomonas	0	0	1	0	0	0
Streptococcus	0	0	0	0	1	0
UDO (undetermined organism)	2	3	4	6	4	2
Staphylococcus	0	0	0	0	2	0
Viral Abortion						
IBR	0	1	1	0	1	2
PI3	0	0	1	1	0	0
BVD	0	0	0	0	0	1
UDO	0	0	0	0	0	0
Mycotic Abortion						
Aspergillus	1	0	1	0	0	0
Mucor	0	0	0	0	1	0
UDO	0	0	0	0	0	0
Parasite						
Trypanosoma	0	0	0	0	0	1
Congenital Defects						
Musculoskeletal	1	1	0	1	0	1
Cardiovascular	1	1	2	2	1	2
Multiple, Metabolic & Others	2	1	1	2	2	2
Eyes & Ears	0	0	0	0	1	0
Nervous	0	0	0	0	1	0
Others						
Twinning	0	0	1	0	1	1
Dystocia	1	0	3	5	1	2
Mummified	0	2	0	2	2	0
Dysmature	0	0	1	0	0	0
Pine Needle	0	0	0	3	0	0
Malnutrition	0	0	0	1	1	0
Specimen Unsuitable	0	0	0	0	0	1
Deficiency Iodine	0	0	0	0	0	1
NO DIAGNOSIS	5	7	10	16	20	23
TOTAL SUBMITTED	18	18	29	39	40	42

TABLE 3. Abortions and Birth Defects in Area 2.

	Year					
Diagnosis	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
Bacterial Abortion						
Bacillis sp	1	4	1	2	0	1
Coliform sp	3	2	2	2	1	2
Corynebacterium sp	8	0	2	4	0	2
Listeria sp	1	3	1	0	0	0
Streptococci sp	3	2	0	0	0	2
Staphylococcus sp	0	0	0	2	0	0
Mixed	3	2	1	1	2	0
Other	4	4	2	0	0	0
UDO (undetermined organism)	14	14	13	19	11	11
Mycotic Abortion						
Aspergillus sp	2	1	2	1	1	2
Mucor sp	1	1	0	0	0	1
UDO	2	0	1	1	0	1
Viral Abortion						
IBR	7	5	4	0	3	4
PI3	1	0	1	1	0	0
BVD	0	1	0	0	0	3
UDO	0	0	0	0	1	0
Parasite						
Trypanosoma	0	0	0	0	0	1
Congenital Defects						
Musculoskeletal	2	5	2	4	0	6
Cardiovascular	3	3	5	3	1	1
Multiple, Metabolic & Other	4	3	3	9	2	2
Eyes & Ears	0	0	1	0	0	0
Nervous	0	0	2	1	1	0
Urogenital	0	1	1	0	0	0
Other						
Twinning	2	2	1	0	1	2
Dystocia	2	3	8	16	4	3
Mummified	6	5	2	6	6	3
Pine Needle	0	0	0	3	0	0
Malnutrition	1	0	0	0	1	4
Other	0	1	2	2	0	0
Specimen Unsuitable	1	0	0	1	0	1
NO DIAGNOSIS	32	42	40	51	28	59
TOTALS	103	104	97	129	63	111

TABLE 4. Abortions and Birth Defects in Area 1

	Year					
Diagnosis	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
Infectious Abortion						
UDO (undetermined organism)	0	0	1	1	3	34
Bacterial Abortion						
Bacillis sp	8	25	11	19	16	23
Coliform sp	17	16	13	6	6	4
Corynebacterium sp	27	8	16	13	10	16
Listeria sp	5	10	4	2	2	3
Leptospira sp	0	8	1	0	0	0
Mixed	5	13	6	3	6	8
Streptococci sp	17	9	3	8	7	10
Staphylococcus sp	1	3	2	6	4	2
Other	19	17	5	7	5	5
UDO	82	84	66	72	39	23
Mycotic Abortion						
Aspergillus sp	10	14	12	12	9	10
Mucor sp	4	2	4	3	4	6
UDO	14	14	6	7	6	6
Viral Abortion						
IBR	32	35	37	10	29	37
PI3	7	4	4	5	2	6
BVD	6	1	1	0	1	11
UDO	1	0	0	4	9	1
Parasite						
Trypanosoma	0	0	0	0	0	1
Congenital Defects						
Musculoskeletal	11	28	9	21	13	22
Cardiovascular	13	19	21	12	6	18
Multiple, Metabolic & Other	20	18	15	16	45	23
Eyes & Ears	0	0	1	0	0	0
Nervous	3	3	5	8	5	2
Alimentary	1	1	0	0	1	0
Skin & Appendages	1	1	2	3	0	1
Urogenital	3	3	1	0	2	1
Other						
Twinning	8	15	11	19	14	8
Dystocia	16	23	37	43	28	35
Mummified	24	26	17	19	25	16
Specimen Unsuitable	6	0	3	7	4	0
Other	0	6	4	6	1	5
NO DIAGNOSIS	214	177	165	187	183	277
TOTALS	575	583	483	519	485	614

TABLE 5. Congenital Defects Diagnosed in Newborn Calves and Feti From Areas 1, 2 and 3.

Date	ALIMENTARY SYSTEM			CARDIO-VASCULAR SYSTEM			EYES & EARS			MUSCULO-SKELETAL SYSTEM			NERVOUS SYSTEM			SKIN & APPENDAGES			UROGENITAL SYSTEM			MULTIPLE METABOLIC & OTHER			TOTAL		
	Area			Area			Area			Area			Area			Area			Area			Area			Area[1]		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10/79-04/80	1	0	0	13	3	1	0	0	0	11	2	1	3	0	0	1	0	0	3	0	0	20	4	2	52	9	4
10/80-04/81	1	0	0	19	3	1	0	0	0	28	5	1	3	0	0	1	0	0	3	1	0	18	3	1	73	12	3
10/81-04/82	0	0	0	21	5	2	1	1	1	9	2	0	5	2	0	2	0	0	1	1	0	15	3	1	54	14	4
10/82-04/83	0	0	0	12	3	2	0	0	0	21	4	1	8	1	0	3	0	0	0	0	0	16	9	0	60	17	3
10/83-04/84	1	0	0	6	1	1	0	0	0	13	0	0	5	1	1	0	0	0	2	0	0	45	2	2	72	4	4
10/84-04/85	0	0	0	18	1	2	0	0	0	22	6	5	2	0	0	1	0	0	1	0	0	23	2	2	67	9	9

[1] Description of Areas:

Area No. 1: Area from Saskatchewan border to B.C. border and from Red Deer to Valleyview.

Area No. 2: Edmonton south to Red Deer, west to Rocky Mountain House, north to Highway 16, and east to Edmonton.

Area No. 3: Wabamun south to Buck Lake, west for 60 km, north to Carrot Creek, east to Wabamun.

POTENTIAL FOR ACID EMISSIONS AFFECTING TRACE ELEMENT NUTRITION OF LIVESTOCK

M.E. Smart

Trace mineral nutrition, not sour gas emissions, is my area of expertise. Trace mineral nutrition and the evaluation of those factors influencing it are very complex. With trace minerals, anything from a severe deficiency to an acute toxicity can exist (Figure 1). To complicate the picture, a large number of interactions can occur (Figure 2); not only with trace minerals and macrominerals, but with vitamins, carbohydrates and proteins. We have problems with energy and protein in livestock rations and these must be corrected before trace mineral supplementation can be implemented.

Some livestock producers believe that if they have a deficiency problem, they should supplement with lots of trace minerals. In the future, toxicities could occur if we are not a little more cautious about our supplementation procedures. With trace minerals, it is not a case of "if a pinch is good, a shovel full is better".

Figure 2 illustrates the complex nature of trace mineral interactions. Copper and zinc are antagonistic to each other. If you increase the zinc in a cow's diet, you will depress the copper. The same thing occurs with copper and selenium. If you live in an area with marginal copper and selenium resources and if selenium alone is added to the rations, you may precipitate a copper deficiency. If copper is added to the ration without adding selenium, you may precipitate a selenium problem. Molybdenum, iron, and sulphur interact together or independently to depress dietary copper availability. Sulphur is of interest this afternoon, as it is one of the by-products of sour gas emissions. A dietary sulphur content of greater that 0.4% will definitely suppress the availability of copper in the diet of ruminants. Sulphur and molybdenum not only interact with copper in the rumen by inhibiting absorption, but also restrict availability to the body if the copper thiomolybdates are absorbed. Aluminum interacts with phosphorus and there is some interaction with other trace elements as well. In summary, there are a large number of interactions which complicate the whole picture of trace mineral nutrition and how it might be influenced by sour gas emissions.

I have found additional data from my research at the Termunde Farm in Lanigan, Saskatchewan, which makes the whole trace mineral question more complex. At the research farm, the drinking water for the cattle contains greater than 2000 mg of sulphates per litre of water. This could potentially simulate the effects that sour gas emissions may have on plant foliage. We have learned that this sulphate concentration did depress the copper availability to the beef cattle that were studied. The interesting thing is that we did not get clinical symptoms associated with a severe copper deficiency. We have cows at the farm that have very little liver copper and yet, clinically, they appear normal.

As a veterinarian, I find it difficult to discuss the role that soil and plant copper levels play in trace mineral nutrition. As the soil pH drops, the copper available to the plant increases and the molybdenum availability decreases. If we wanted to start to acidify our alkaline soils, we might be improving the copper availability to the plant. Plant cultivars also differ in their ability to assimilate copper and other minerals. Clovers do not take up sulphate nearly as readily as grasses. So perhaps animals grazing grasses in an area of sour gas emissions might have more problems with sulphates taken up through the foliage than cattle grazing legumes grown in similar area.

In Saskatchewan we find that most of our grains and cereal hays are low in copper, zinc and manganese; whereas the copper, zinc and manganese concentrations in legume plants are not quite as low. Environmental factors also influence the trace mineral content of plants. During a drought, the copper concentration in plants will increase because the plants are growing very slowly. Other years, a lush growth associated with a high rainfall will decrease the copper concentration of plants, as well as decrease the concentrations of other trace elements. We also see differences in the plant trace mineral concentrations due to fertilization; either by an increase in the concentrations of the trace elements or a decrease.

Other factors may influence the concentration of trace minerals in cattle; one of these factors is age. The enzyme systems in the fetus are very immature. Thus, the developing fetus accumulates copper in the liver at quite a rapid rate (Figure 3). If the dam of this fetus is deficient in copper, then at about 180 days of gestation, the fetus stops accumulating copper in its liver and a dramatic decline occurs in liver copper concentration. We believe that at birth the fetal liver copper concentration must be greater than 300 mg/kg dry weight for that animal to be considered to have adequate copper reserves. Unfortunately, we don't know what happens to the fetus if we feed excessive copper to the dam during pregnancy. We don't know if the fetus continues to accumulate the copper at a very rapid rate and eventually reaches toxic concentrations. At birth, the enzymes in the liver of the calf mature and copper is gradually released from the liver to support the development of the calf. Thus, the trace mineral metabolism in the fetus is different from the adult. The adult can exist fairly well with a low level of copper and some other trace minerals and not manifest clinical disease.

The physiological or pathological state of the animal will also influence liver and plasma copper concentration. Stress plays an important role in trace element nutrition. The ability of the animal to adequately handle stress can be altered by deficiencies of iodine, zinc, copper and selenium. When an animal responds to stress, alterations occur in the trace mineral concentrations in liver and plasma. We are just beginning to understand these factors. Pregnancy drains trace minerals from the dam. At calving, we see a shift in the zinc concentration. The plasma zinc drops significantly and the liver zinc increases. We don't completely understand why this happens.

Disease also alters trace element concentrations. A trace mineral deficiency may result in the animal having difficulty in responding to a disease. The history of one suspected copper-deficient herd involved an owner who was having a great deal of difficulty treating both lice and coccidiosis. Once we diagnosed the problem as a copper deficiency, and supplemented the diet accordingly, the parasitisms self-corrected. Perhaps the improvements were coincident with time. Disease may alter plasma levels. So if one uses plasma concentrations of copper and zinc as the sole criteria for evaluating trace mineral deficiency or excess, one must be wary if an underlying disease is present in a herd, since that disease may alter the plasma levels. Normal copper concentrations might be determined when actually the animals were deficient. Also, very low plasma zinc concentrations might be reported when, in fact, the animals had an adequate zinc status.

The species and the breed of animal play a significant role in copper metabolism. Sheep, especially certain breeds, are more sensitive to copper toxicity than cattle. Our research with Simmental cattle and some of the other exotic breeds suggests that they tend to manifest clinical symptoms of copper deficiency more readily that Hereford or Angus. What I think is partly responsible for this is that we have, through culling, selected Hereford and Angus cattle that have adapted to low levels of dietary copper. We then bring in exotics that haven't been culled over the century and we see problems start to occur. Perhaps our ancestors, when they were starting with Hereford and Angus breeds saw similar problems.

I would like to discuss some clinical signs associated with copper and zinc deficiency (Figures 4 and 5). Because of the complex nature of the trace element deficiency in copper, we do not always see manifestations of clinical disease. As I have said, the Hereford cattle at the Termunde Research Farm are quite deficient in copper and yet we don't see a lot of the clinical problems other than perhaps depressed weight gains. Anemia (a low red blood cell count) is a problem that I have observed in several copper deficiency cases.

Lameness is a serious problem in young growing calves. I will show slides of calves exhibiting this lameness. The calves have a scruffy haircoat and swollen, painful fetlocks and hocks. Researchers have depleted the copper in groups of calves and have only seen lameness in those animals that were depleted with molybdenum. When copper depletion was obtained using high levels of dietary iron, no lameness was observed. Copper deficiency also causes a lack of pigmentation, thus haircoats fade and become bleached out. This has to occur when hair is growing not during quiescence.

Infertility, discussed in relationship to copper deficiency, is a debatable point. Some researchers believe that copper deficiency does cause infertility. Other researchers believe this is due more to a molybdenum excess, since infertility occurs only when there is an excess of molybdenum in the ration. When copper deficiency is created by other means, infertility is not a feature. Scouring in adult cattle is another symptom often associated with a molybdenum excess. In addition, we have seen cardiovascular changes involving myocardial fibrosis and degeneration. These cattle tend to have an increased susceptibility to stress. A common problem in sheep associated with copper deficiency is wool breakage. Also lambs, born copper deficient, develop a nervous system disorder involving staxia and paresis. It is very difficult for me to say that you will see specific clinical signs associated with copper deficiency.

Zinc is a trace element about which our knowledge is relatively limited. By reducing zinc in the diet, we can create certain lesions in cattle. I know that, in Alberta, zinc is added to cattle rations rather indiscriminately to alleviate some foot problems we see in cattle. Clinical features associated with zinc deficiency are parakeratosis and inflammation of the skin. This initially starts at the bulbs of the heel and around the dew claw. These lesions then extend up the hock, and can involve the base of the teats. When severe enough, the lesions can involve the skin of the nose and muzzle. Cattle will also be extremely thin and immunodepressed. Bulls and heifers can exhibit hypoplasia of the testicles or ovaries, respectively. We are not sure of the normal concentrations of zinc in the liver and plasma. Rough guidelines are available, but we still don't know the whole answer.

The most common and most accessible way of measuring the trace element status of animals is by taking blood samples. Feed samples can also be used to monitor the trace mineral concentrations in the diet. Plasma copper is an indicator of copper status but there are certain problems associated with this. For example, we compared the plasma copper concentrations of weaned Simmental calves in herds known to be either normal or copper deficient. By comparing the assayed concentrations with published normal values (Table 1), we found that over 95% of the calves in the normal herds had normal plasma coppers, but 50% of the calves from the deficient herds also had normal plasma coppers. This is because plasma copper fluctuates among animals.

We have found that calves born to heifers have lower plasma coppers at weaning than calves born to adult cows. The copper values selected as standards for normal, deficient and marginal status can be debated as arbitrary. A recent article suggested that plasma copper should be used as the only indicator of copper status; for, if the values of plasma copper are consistently low, then a problem with copper deficiency does exist. In our research, we have observed normal plasma copper when the liver copper concentrations were extremely low.

The season of the year and pregnancy also change plasma copper concentrations (Figure 6). Over the pasture season (May - September), plasma copper increases despite a decrease in forage copper concentrations and a decrease in liver copper concentrations. By July and August, in most of our pastures in Saskatchewan, there is a significant decline in both liver (vs plasma - see Fig. 6) copper and zinc content. The nutrient value of pasture forages also declines dramatically. So if a farmer is planning to winter his cattle over on stubble or on winter pastures, he must be aware that the quality of pastures has dropped off to a point where there is a trace element problem and also a problem with energy and protein.

Plasma copper concentrations are lowest in March. This decline occurs both in open heifers and pregnant cows. It occurs in supplemented as well as non-supplemented cattle, but the decline in supplemented cattle is not as dramatic as it is in the non-supplemented animals. Thus, one must be very cautious in interpreting plasma copper concentrations because of the influences of seasonal variation, age, and the effect of diet. Cattle seem to have an ability to maintain plasma copper concentrations despite declining liver copper concentrations at certain times of the year. Table 1 illustrates arbitrary values that were established through a review of the literature.

Unfortunately, there are a lot of unanswered questions. We know from our water trials that if the total sulphur in the ration is greater than 0.4%, we have problems with copper availability. I mentioned very little about selenium. We have done some selenium trials in our research but we have found very little problem with selenium despite the high sulphur content of the water. There may be other more complex interactions.

Selenium is deficient in grey-wooded soils and so one may be dealing with a selenium deficiency in these areas rather than any complicating factors associated with sour gas. Selenium deficiency, apart from the white muscle disease that is seen in young calves, can result in weak or stillborn calves, or calves with a high incidence of scours unresponsive to conventional treatment. Adult cattle may have reproductive problems and retained placentas. Unfortunately, these reproductive problems can be complicated by other problems, such as a deficiency of protein or vitamin A or other trace elements in the diet. In conclusion, the whole concept of trace element nutrition is a very complex problem.

Questions/Answers

1. Question. On that last slide, where you had the difference in copper content in the liver, was there any difference in performance in those calves in the various groups? Or did you try to measure that?

   Answer. We did measure the performance of the calves and found very little difference in their performance. But one must remember that although these calves showed an improvement in liver copper concentrations, they were still very deficient in liver copper. In one trial, we injected a group of calves with copper (Coprin®, Glaxovet®) and we saw an improvement in the average daily gains for the first 90 days after we injected them. We increased the liver copper concentrations in these calves to a reasonably high concentration. I do know that there is a certain threshold concentration of copper in the liver that must be passed before we see any improvement in the average daily gains. In this trial, the threshold was 5 umol/g dry weight.

2. Question. You have used both plasma and liver copper for assessing the changes. Have you thought of using whole blood? Because there is a considerable amount of copper in the red cells.

   Answer. We haven't used whole blood mainly because we haven't developed a technique for the use of whole blood. There are a number of techniques and analyses that we have not done because of the cost of doing such analyses.

3. Question. We have a lot of problems with sand cracks. Now, what's the story?

   Answer. Some people think that zinc deficiency is the reason for seeing sand cracks. Other researchers believe there is a hostile environment for the foot. There are still a lot of questions to be answered. It is definitely breed related; we very seldom see sand cracks in Holstein breeds, but we see it frequently in beef cattle such as Simmentals, Herefords and Charolais. It's important to remember that sand cracks do not occur at the toe but they start at the coronary band and grow out as the foot grows. It is a very complex problem and I know that in some areas where they have supplemented with zinc and copper there has been a decline in the number of sand cracks.

4. **Question.** When you brought your dietary sulphur requirements down to less than 0.4 or greater than 0.4% of the total, it would seem that you then didn't distinguish between, say, the effect of organic sulphur in plants as opposed to sulphate in water. Is there, in fact, a difference?

   Answer. I suspect that there may be. The only time we've ever brought it up high enough, it has been through the water or by adding sulphates to the ration. We really haven't done any research with the plants and the sulphate levels in them.

5. **Question.** The other thing that surprised me, and this is more in the form of a comment, is that you talked about 1000 ppm sulphate as being a level of concern, a high level. In fact, in most parts of central or southern Alberta, many farmers using ground water as a source of water for their animals would exceed

that by quite a bit, and the same would be true in southern Saskatchewan I suspect.

Answer. Yes, that's true. In Europe, they talked about 500 ppm sulphate as being a concern. I'm being conservative by saying 1000. Our water would go much higher than that, usually around 2000 ppm at the Termunde Research Farm. The sulphate content of alkaline sloughs that are often used for watering livestock in Saskatchewan may reach as high as 20,000 ppm. We do run into problems in these cases with other diseases not associated with copper deficiency or trace mineral deficiencies. We have diagnosed thiamin deficiency or polioencephalomalacia in cattle drinking this slough water. I think part of the problem in this case is associated with water intake. They just don't get enough water so they have a problem with dry matter intake. Thus, there is a problem with energy and protein in these cattle.

7. Question. Sheep will apparently take in even more saline water than cattle. Does the same thing occur in sheep as well?

Answer. We haven't monitored sheep.

Table 1. Expected plasma and liver copper concentrations for adult cattle.*

	Plasma		Liver	
Copper Status	mg/ml	umol/L	mg/kg DM	umol/g DM
Deficient	.06 - .55	.9 - 8.7	3.5 - 35.0	.06 - .55
Marginal	.55 - .70	8.7 - 11.0	17.5 - 70.0	.28 - 1.10
Adequate	.80 - 1.20	12.6 - 18.9	87.5 - 525.0	1.4 - 8.3

*Modification of Veterinary Trace Mineral Deficiency and Toxicity Information (1980) British Columbia Ministry of Agriculture.

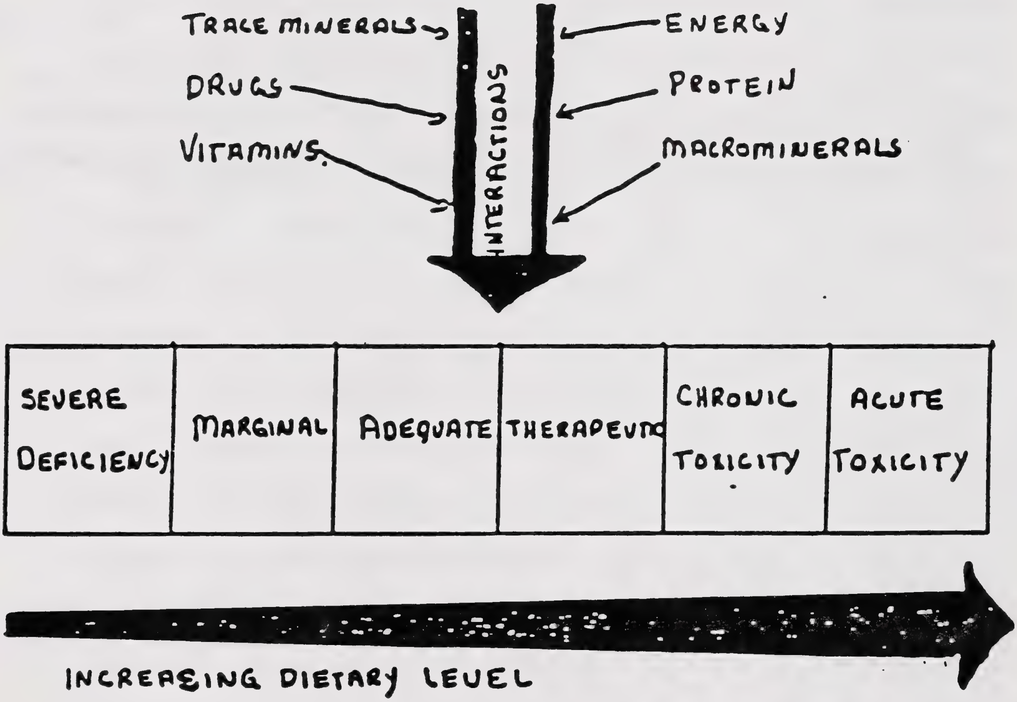
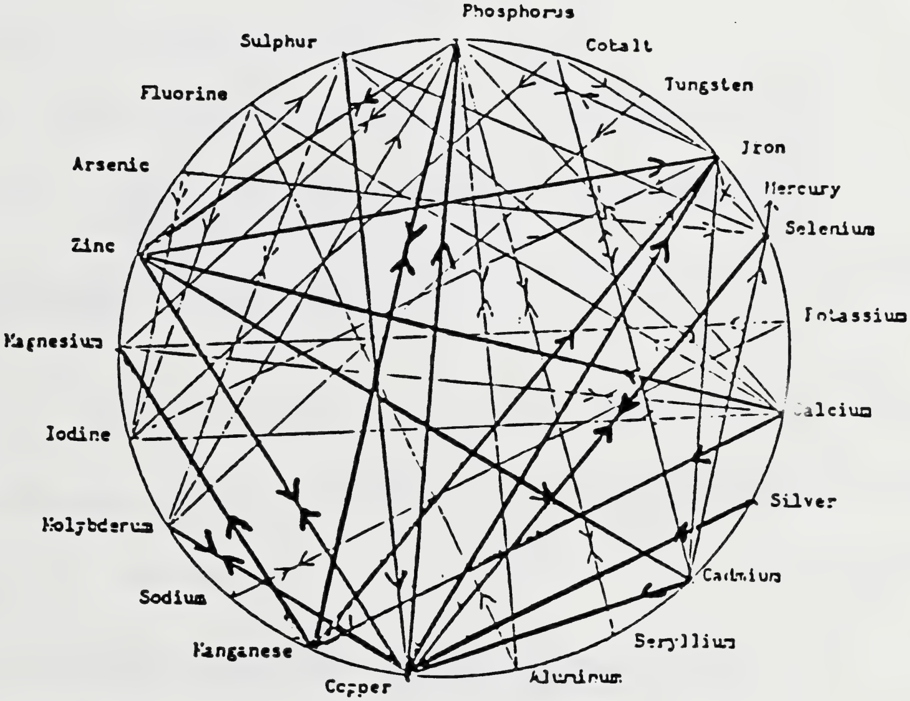

TRACE MINERALS
DRUGS
VITAMINS
INTERACTIONS
ENERGY
PROTEIN
MACROMINERALS
SEVERE DEFICIENCY
MARGINAL
ADEQUATE
THERAPEUTIC
CHRONIC TOXICITY
ACUTE TOXICITY
INCREASING DIETARY LEVEL

Figure 1.

Mineral Interrelationships
(from Dr. A.L. Tillman)



Significance of the arrows - -

Sulphur - - -→- - - Selenium. Sulphur is antagonistic to selenium. An excess of sulphur will prevent the absorption and utilization of selenium.

Calcium ——→←—— Phosphorus. Calcium and phosphorus are mutually antagonistic. An excess of either will prevent the utilization of the other.

Figure 2.

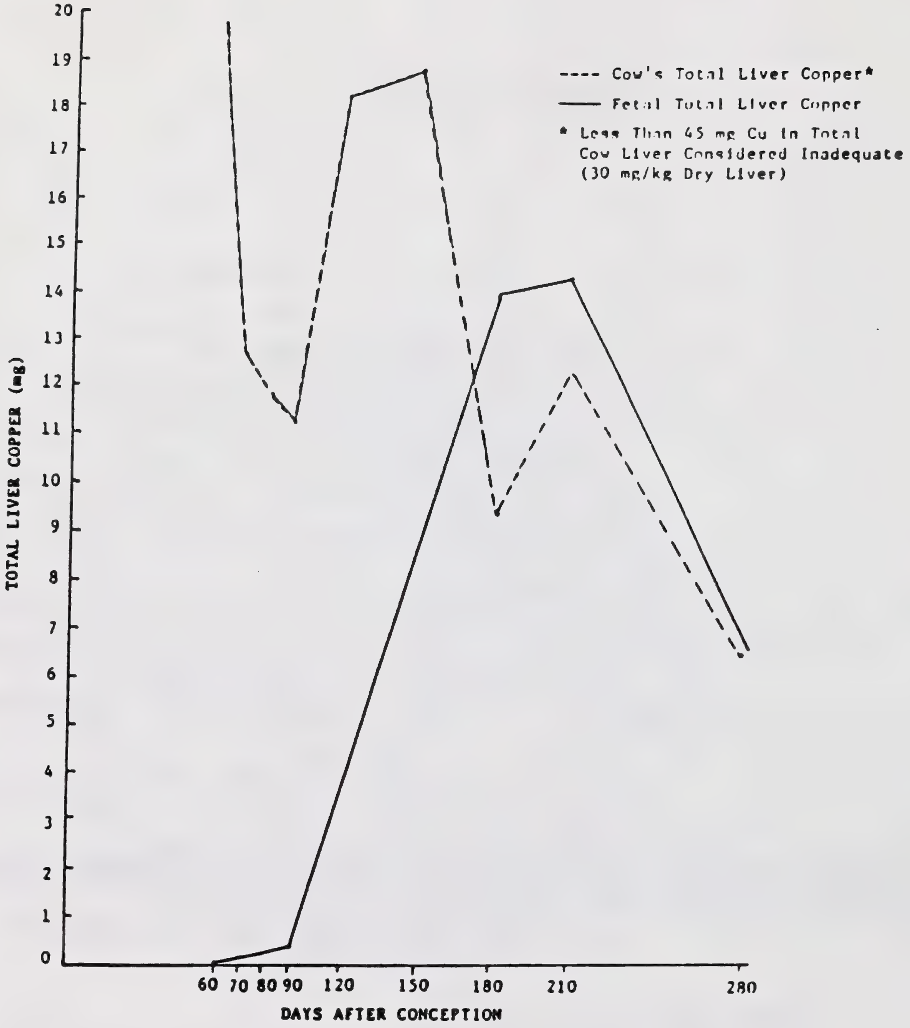


Figure 3. Dam's Total Liver Copper Concentration (mg) and Fetal Total Liver Copper Concentration (mg) During Gestation.

COPPER

CLINICAL AND PATHOLOGICAL FEATURES:

ANEMIA - DEFECTIVE HEMATOPOIESIS -- MICROCYTIC ANEMIA
- FAILURE OF IRON STORE MOBILIZATION -- INCREASED IRON STORES

LAMENESS - DEFECT IN ORGANIC MATRIX OF BONE -- SWOLLEN AND PAINFUL
- FAILURE OF COLLAGEN CROSS LINKAGE AND MATURATION -- EPIPHYSEAL REGION

DEPIGMENTATION - DEFECT OF MELANIN FORMATION -- FADED HAIR COAT

INFERTILITY:

SCOURS: DEPLETION OF CYTOCHROME OXIDASE -- VILLUS ATROPHY

CARDIOVASCULAR: FAILURE OF COLLAGEN AND ELASTIN CROSS LINKAGE -- MYOCARDIAL DEGENERATION AND FIBROSIS

PARASITISM: INCREASED SUSCEPTABILITY TO STRESS

NERVOUS DISORDERS: DECREASED CYTOCHROME OXIDASE
: DEMYLINATION, NEURONAL NECROSIS -- ATAXIA

WOOL BREAKAGE: DEFECTIVE DISULPHIDE BONDS IN KERATIN

Figure 4.

ZINC

CLINICAL AND PATHOLOGICAL FEATURES:

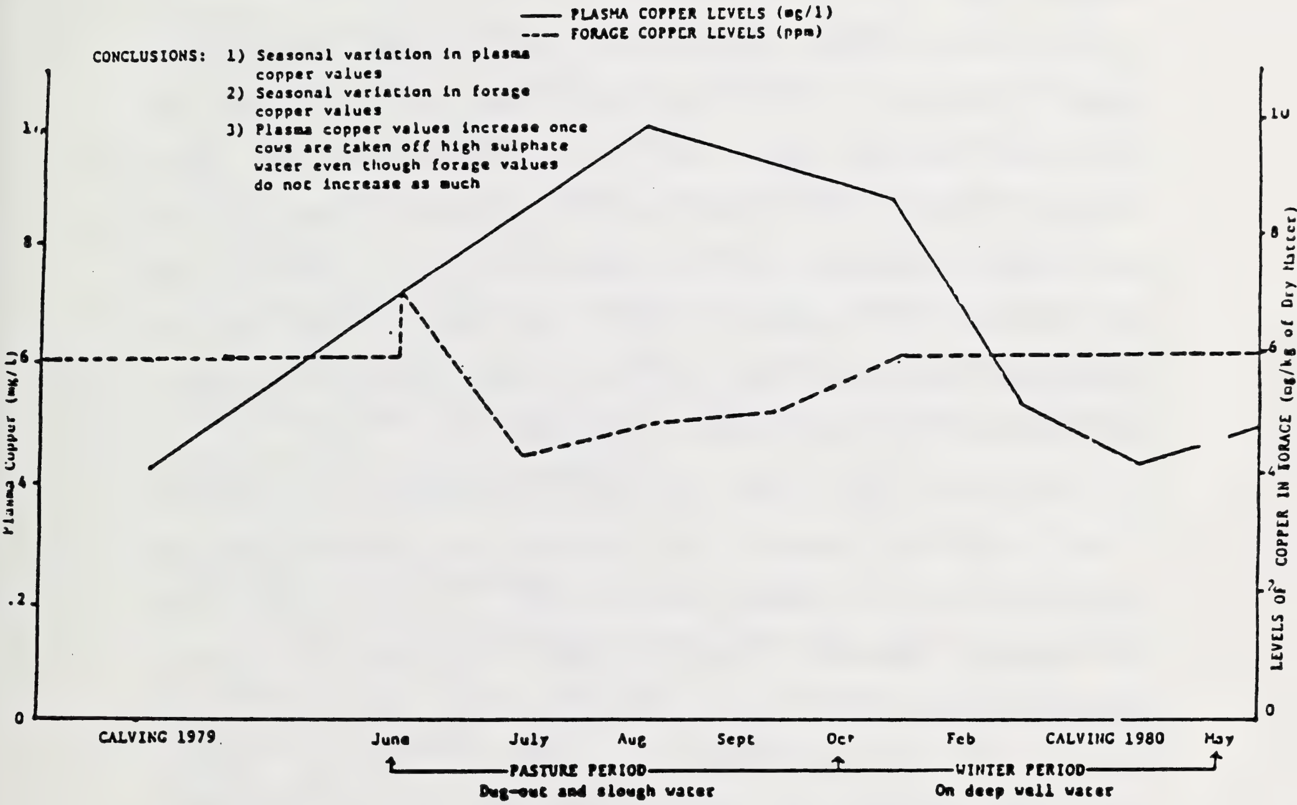
SKIN - PARAKERATOSIS AND INFLAMMATION
- BULBS OF HEEL - AROUND DEWCLAWS
- EXTENDS UP HOCK
- BASE OF TEATS
- NOSE AND MUZZEL

GENERAL DEBILITY:

INFERTILITY - IMPAIRED GONADAL MATURATION

INCREASED SUSCEPTIBILITY TO INFECTIONS - IMPAIRED IMMUNE SYSTEM

Figure 5.



CONCLUSIONS:
1) Seasonal variation in plasma copper values
2) Seasonal variation in forage copper values
3) Plasma copper values increase once cows are taken off high sulphate water even though forage values do not increase as much

Figure 6. The Effect of Copper Intake, Pregnancy and Season on Plasma Copper Levels of Commercial Hereford Cows.

MEASUREMENT OF ACID FORMING EMISSIONS IN ALBERTA AIR

A.R. Schultz

INTRODUCTION

Acid rain has come a long way since the 1970's when studies of the aquatic ecosystem in relatively remote areas led to findings of significant negative impact, and the conclusion that long range transport of acid forming emissions was responsible. These findings heightened the awareness that the atmosphere was not a limitless sink for dumping air contaminant wastes, and that dilution of air contaminants by emitting them from tall stacks was not an acceptable solution or air pollution control alternative.

Since those early days "acid rain" has become a key research issue, a political football, the subject of many conferences and the object of considerable debate and controversy. A recent issue of the Environmental Management Review (1986) illustrated the various perspectives on the acid rain issue by quoting people such as Lee Thomas, US EPA Administrator, the Hon. T. McMillan, Federal Environment Minister, US Presidential Envoy Drew Lewis. It also quoted industry representatives and environmentalists. The quotes reflect some widely divergent opinions as to the extent or severity of the problem. These differ in particular in the perception of priority with which the acid rain issue should be tackled.

As a Canadian, I am concerned that the acid rain issue be addressed in time to avert permanent damage to eastern Canada'a lakes and forests. I hope that my children will someday have the opportunity to marvel at the glorious fall colors of a maple tree forest in Quebec's eastern townships. As an Albertan, I am grateful for the fact that, in general, while acid rain is a potential issue in our province, and requires attention, it is not a pressing current problem. Therefore, the emphasis can be placed on prevention versus correction. At the same time, it should be recognized that the localized release of acid forming emissions, especially during some plant upset conditions or times of poor atmospheric dispersion conditions, have the potential for impacting the areas immediately downwind of the emission source.

WHAT GOES UP MUST COME DOWN

It follows that if one has a good handle on what is being emitted in terms of acid forming emissions, this provides a good basis for evaluating potential impact. In Alberta, source and emission inventories for SO_2 have been compiled and published since 1974, and for NO_x since 1976. Figure 1 summarizes the SO_2 emissions by year, both licensed and observed for 1974 - 1985. It is worthwhile noting that the gap between licensed and observed actual emissions has widened over the past ten years, and that the total actual SO_2 emissions are currently less than half of the licenced SO_2

emissions. Considering the fact that clean-air-license-emission-limits reflect the implementation of best practicable control technology, and considering that stacks are designed for adequate dispersion of the air contaminants sufficient to meet Alberta's air quality standard, this means that on average Alberta industry is controlling air pollution very well and is generally operating well within license limits.

Looking at the last five years, it can be noted that despite the fact that the number of plants increased from 135 to 180, the total licensed SO_2 emissions increased only slightly, while actual observed emissions have remained about the same (Figure 2).

Figure 3 gives further details of the SO_2 emission contributions from various industry sectors. In all cases, except the sour oil production facilities, actual SO_2 emissions are well below the licensed limit values. The sour oil production facilities are not licensed due to their large number and generally low SO_2 emission levels; however, on occasion these small sources have been determined to cause localized impact, and corrective action such as better incineration or flare design has been required and implemented. When comparing different contributing industrial groups, it is important to note the difference in the SO_2 emission vertical scale between the various industrial group graphs.

Other acid forming emissions generally considered are the oxides of nitrogen (NO_x). The main forms of the oxides of nitrogen considered here are the nitric oxide (NO), which is the primary emission form and the more visible, and more toxic, nitrogen dioxide (NO_2), which can be formed readily by the oxidation of NO by ozone in ambient air. For source and emission monitoring purposes, the total oxides of nitrogen are considered. Figure 4 shows the nitrogen oxides emission trend from 1980 - 1984 and identifies the major contributing source categories. It should be noted that major industrial sources contribute only slightly more than one-third of the total nitrogen oxides and that transportation sources are an approximately equivalent major oxides-of-nitrogen emission source.

Figure 5 gives a further breakdown of the relative contribution of major industrial sectors in Alberta, where the natural gas processing industry is identified as the major industrial source of oxides-of-nitrogen emissions. Over the five year period it can be noted that both the major industrial contribution and the total oxides-of-nitrogen emissions for the province have not changed significantly.

HOW ARE EMISSIONS MONITORED?

For years emissions were calculated on a process balance basis. For example the amount of inlet gas processed was measured continuously and analyzed periodically for its sulphur content. On the other end of the process, the amount of elemental sulphur produced was measured and the difference taken to be emitted to the atmosphere in the form of SO_2. Measurement errors, particularly in the amount of liquid sulphur produced led to some interesting emission figures, although the longer term average emission figures were probably representative. For flaring gas plants, the above general approach is still applicable; however, since there is no elemental sulphur produced and the sulphur inlet goes to flare, the calculated emissions are expected to be reasonably accurate.

Actual measurement of the stack emission gases is conducted periodically to establish emission gas flow rate and composition. Such manual stack surveys, while quite accurate if conducted properly, are relatively expensive. They are required to be done only once per year for small plants and up to eight times per year for some of the larger industries. Depending on the size of the stack, a representative stack test may take from about 1 to 3 hours and a stack survey consists of three representative stack tests. Therefore, in terms of actual measurement, an annual stack survey may only represent some 3 to 9 hours of emission testing for the whole year. However, this data can be used to calibrate an emission calculation method or it may be compared with data from a continuous emission monitor (CEM).

A CEM provides the best indication of actual emission variations and accurately reflects the effect of process upsets on emission levels. Most larger SO_2 emitting industries in Alberta are required to have a SO_2 CEM unit. Currently a total of 62 SO_2 industrial CEMs operate in Alberta. To ensure more accurate and representative CEM results the Department of the Environment recently developed sulphur dioxide CEM guidelines which include operation and quality assurance requirements. Guidelines for oxides-of-nitrogen CEMs have not yet been developed, and it is a low priority because there are only six oxides of nitrogen CEMs currently operated by industry in Alberta.

HOW DO WE MEASURE WHAT IS COMING DOWN?

Knowing what is being emitted from a specific source, together with atmospheric stability, wind speed, and direction would allow one to calculate the expected ground level concentration at specific points downwind of the source. While there are numerous applications for atmospheric dispersion modelling, quite often we cannot get a good measure of emission rates from sources such as flare stacks or sulphur remelting or forming. Therefore, ambient air quality monitoring at specific receptor points of concern can provide valuable information. Industry self-monitoring has often been cited as an area for concern. By conducting regular inspections and station audits, Alberta Environment tries to ensure that the reported data is representative and valid. For Alberta Environment to be doing all the monitoring would require considerable additional resources; whereas, under the current system, the polluting industry pays the major monitoring costs.

The number of continuous monitoring stations and length of operation in the vicinity of specific industrial plants varies from one station operated for 1 or 2 months per year to networks of up to five stations operated year round in the vicinity of some of the larger plants. In addition, static exposure cylinder (total sulphation) monitors placed for a month at a time around the plants provide useful trend information. Table 1 lists both continuous ambient monitoring stations as well as the exposure cylinder networks operated by industry in Alberta. The sour gas industry operates the majority of the SO_2 and H_2S ambient monitors, while the power plants have the greater number of NO_x ambient monitoring stations. The exposure cylinder network represents extensive data points especially in the vicinity of the larger plants which may have 40 or more stations. Contours of equal total sulphation levels can provide an indication of primary impact zones in the immediate vicinity of the plants.

Another measure of the acid forming emissions, and one directly related to "acid rain", is the precipitation quality monitoring network operational in Alberta. Figure 6 depicts the locations of three different types of precipitation quality monitoring stations. The Canadian Network for Sampling Precipitation (CANSAP) stations were operated by the federal government until the end of 1985; nine similar stations are still operated by Alberta Environment. There are three stations operated under the Alberta Acid Deposition Research Program (ADRP) and two newly proposed daily sampling stations, one near Esther operated by Environment Canada as part of the Canadian Air and Precipitation Monitoring Network (CAPMON) and one near High Prairie

(Alberta Precipitation and Air Chemistry station) operated by Alberta Environment. Although there are a number of differences between the sampling methodologies, a primary one is that both the CANSAP and Alberta Environment older stations collect monthly samples, whereas the CAPMON stations take daily samples and the ADRP stations collect event samples. The precipitation samples are analyzed for various constituents as given (Table 2).

Before discussing some of the monitoring results, two additional ambient monitoring methods should be mentioned, the industrial soil pH monitoring program and the mobile monitoring program. The soil pH monitoring program arose primarily out of a concern for monitoring the impact on soils of elemental sulphur emanating from sulphur handling and storage facilities. While the soil pH would definitely be impacted by high wet deposition rates of acid forming emissions, our monitoring program to date has shown the primary impact in terms of depressed soil pH, and the need for liming has been limited to the immediate vicinity of sulphur blocks or sulphur handling facilities.

The total soil pH program was reviewed last year and a joint industry government task force has come up with major modifications of the program. These involve expanding the soil pH monitoring program by including elemental sulphur analysis and by modifying the sampling and analytical methodology to make the whole program more meaningful. The changes will be incorporated into the new Air Monitoring Directive AMD-86-1 which is expected to be issued early in 1987.

Finally, some mention should be made of the mobile monitoring program. This involves SO_2 and H_2S monitors mounted in designated vehicles that analyze ambient levels of these gases in a mobile mode. While this method may not be that applicable to the long range transport of air pollutants, it has proven invaluable in tracing down-field related operational problems or detection of plumes downwind of a specific plant. The benefit of mobility allows the unit to move with the plume and, thus, maximize the measure of how the plume impinges. The mobile monitors have been able to detect small concentrations of H_2S and SO_2 several miles from the source, but generally show the highest concentrations within a distance of less than 1 km unless the source is an elevated plume such as a 400 foot incinerator stack. A further refinement of the mobile monitoring system is the Alberta Environment mobile laboratory. This unit has its own navigational system and data handling computer on board, and is capable of running up to 16 different parameters simultaneously.

WHAT DO THESE MEASUREMENTS OF ACID FORMING EMISSIONS SHOW?

For the most part, a review of industrial compliance with licensed emission limits and the Clean Air (Maximum Levels) Regulations shows a very high degree of compliance (Table 3). Plant process upsets such as emergency equipment failure or even plant startup/shutdown may result in short term contravention of the licensed or regulated levels. However, these are likely to be beyond the control of the operator provided the frequency of such occurrences is reasonable. Corrective programs have been implemented whenever the source and ambient air monitoring programs have shown problems. These programs have resulted in improved industrial compliance.

Data regarding the precipitation monitoring network was presented at a meeting of the local section of the Air Pollution Control Association (Lau and Das, 1986), so only some highlights will be reviewed here. Figure 7 gives representative precipitation quality in Alberta over the 1978 - 1984 sampling period. Comparison was done on a molecular basis and not by weight. This data shows the calcium, sulphate and ammonia ions to be the major ions with the hydrogen ion to be the least important. It is significant that there appears to be no correlation between hydrogen ion, sulphate, or nitrate; that is, an increase in the sulphate levels did not mean a corresponding increase in acidity in the precipitation samples. Table 4 gives volume weighted averages of the various parameters for the 1978 - 1984 time period. A review of the annual data for the stations showed no significant trend. However, there was high natural variability, especially in calcium ion levels. These variations were likely affected by variations in the precipitation amounts.

The spatial distribution of volume-weighted average pH levels for 1978 - 1984 are given (Figure 8). Average pH values ranged from 5.2 in Beaverlodge to 6.1 in Lethbridge. This variation from north to south likely reflects the larger contribution and presence of wind-blown alkaline soil dust in southern Alberta. The reference pH is 5.6, which is the theoretical pH of distilled water in equilibrium with CO_2 in the atmosphere.

Figure 9 gives the pH frequency distribution plot for the 1978 - 1984 data. The lowest pH measured was 4.3. Only 5% of the total samples had a pH value less than 5. The wet deposition levels for Alberta are given (Figure 10). Although the levels are well below the 20 kg sulphate/ha/year which has been set by Environment Canada as the level indicated as providing adequate protection of surface waters, it is recognized that dry deposition levels may play a greater part in Alberta than in eastern Canada. Dry deposition rates of acid forming emissions are not readily measurable and are undergoing further study in western Canada.

Finally, let me reiterate the usefulness of mobile monitoring in assessing the potential impact in the immediate vicinity of a specific source. It should be noted, however, that mobile monitoring requires greater care in quality assurance and quality control to ensure that valid data is being generated. Alberta Environment is currently developing a mobile monitoring Air Monitoring Directive which should serve as a useful reference guide.

CONCLUSIONS

1. Alberta has significant emissions of SO_2 and NO_x which are the primary acid forming emissions. With our increasing number of sources the total emission levels have not changed significantly.
2. Considerable monitoring is being done with respect to acid forming emissions in Alberta.
    - Extensive industrial monitoring of stack emissions, especially for SO_2, is being done by manual stack survey and continuous emission monitors.
    - An extensive network of total sulphation cylinders is in place throughout the province.
    - Considerable ambient monitoring for SO_2 and NO_x is conducted in the vicinity of industrial sources.
    - Soil pH levels are being monitored in the vicinity of sulphur blocks or handling facilities.
    - Precipitation quality sampling is carried out throughout the province to establish wet deposition levels of acid forming emissions.
    - Mobile monitoring is effective for monitoring the more immediate vicinity of specific sources.
3. The measurement of acid forming emissions show:
    - a generally high degree of industrial compliance with licensed and regulated levels.

- where source and ambient monitoring has shown problems, corrective action has been implemented.
- average wet sulphate deposition rates are 9 kg/ha/year compared to a national target of 20 kg/ha/yr.
- monitoring, surveillance and ensured compliance must continue; because, with our mobile monitoring program, we continue to find sources that will impact on the immediate environment.

REFERENCES

1. Environmental Management Review. (1986). Volume 1, No. 11, pages 81 - 82. Published by R. A. Owens Environmental Services Ltd. Calgary, Alberta.
2. Lau, Y.K., and Das, N.C. (1985). Precipitation quality monitoring in Alberta. Presented at the PNWIS - APCA 1985 Annual Meeting in Calgary, Alberta.

Table 1. Continuous Ambient Monitoring Stations Operated by Industry.

1. Continuous Ambient Monitoring Stations

Industry type	# of SO_2 Monitors	# of H_2S Monitors	# of NO_2 Monitors
Sour Gas	90	83	0
Chemical Plants	0	0	4
Heavy Oil	16	16	1
Fertilizer	3	0	8
Oil Sands	10	7	1 (NO_x)
Power Plants	9	0	12 (1-NO_x)
Pulp and Paper	2	2	0
Refineries	2	2	0
SIA	2	5	0
TOTAL	134	115	26

2. Exposure Networks

Industry type	# of Total Sulphation	# of H_2S
Sour Gas	1019	1019
Oil Sands	80	80
Heavy Oil	184	208
Refineries	34	38
Fertilizer	24	0
Pulp and Paper	18	18
Power Plants	111	0
Chemical Plants	4	0
Sulphur Handling	4	4
TOTAL	1478	1367

Table 2. Analytical Methodologies Used by Alberta Environment to Determine Air Quality and Acid Deposition.

Parameters	Analytical Method
pH	Electrometric Measurement by pH Meter
Specific Conductance	Resistance Measurement by Conductivity Meter
Sulphate	Ion Chromatography
Nitrate	Ion Chromatography
Chloride	Ion Chromatography
Phosphate	Ion Chromatography
Ammonium	Ion Chromatography
Sodium	Ion Chromatography
Potassium	Ion Chromatography
Calcium	Atomic Absorption
Magnesium	Atomic Absorption
Bicarbonate	Theoretical Calculation

Table 3. Clean Air Act Compliance for July, 1984 to June, 1986.

Industry Type	With Licence Conditions	With Maximum Levels (Ambient)
Sour Gas	99.60	99.75
Oil Sands	98.35	99.45
Power Plants	100	100
Fertilizer	99.89	99.91
Pulp and Paper	98.30	96.94
Refineries	99.87	99.96
Chemical Plants	99.95	99.91
Heavy Oil Plants	100	99.33
Cement	99.55	--
Fibreglass	100	--
Steel and Foundries	100	--
Overall	99.81	99.73

Note: a) Overall, the ambient readings have been within the Clean Air (Maximum Levels) Regulation 99.73% of the time. There were approximately 1,772,000 hours of continuous ambient monitoring carried out by industry in Alberta during the period July 1, 1984 to June 30, 1986. During this period there were 4800 hours of readings in which the Clean Air (Maximum Levels) Regulation was exceeded.

b) Overall industry in Alberta was within the Clean Air License requirements based on stack limits 99.81% of the time during the period July 1, 1982 to June 30, 1986. There were approximately 3,850,000 hours of in-stack monitoring carried out by industry. During this period 7,350 hours of readings were reported in which license requirements based on stack limits were exceeded.

c) During this time period, about 1,170 hours of uncontrolled unlicensed and accidental releases occurred from all industry groups. The majority of these were from the oil sands, sour gas and pulp and paper industries.

Table 4. Volume-weighted Averages of Parameters Measured for 1978-1984[1] (concentrations in μ equivalents/L, specific conductance in μ siemens/cm).

	pH	Specific Conductance[2]	SO_2^{4-}	NO_3^-	Cl^-	HCO_3^-	HN_4^+	Na^+	K^+	Ca^{2+}	Mg^{2+}
Beaverlodge	5.17	10.3	28.9	10.0	5.7	4.1	25.8	12.6	10.4	35.3	8.8
Calgary	5.77	19.4	65.4	20.6	6.9	23.3	40.8	17.2	4.2	93.0	23.3
Coronation	5.46	12.7	39.3	16.6	5.2	3.3	15.7	19.5	2.9	32.3	8.7
Edmonton	5.45	11.0	39.0	16.1	5.4	3.3	29.6	6.8	4.2	26.1	10.9
Edson	5.26	10.3	31.6	8.6	5.1	6.2	8.2	9.2	2.6	33.5	7.1
Fort McMurray	5.61	14.4	38.4	11.6	12.4	9.8	3.4	13.6	4.5	59.5	31.3
Lethbridge	6.06	22.9	47.8	24.6	10.3	18.8	26.1	11.2	2.7	132.6	28.6
Red Deer	5.39	12.9	37.0	15.6	9.4	8.0	36.2	16.5	3.7	30.9	7.3
Rocky Mountain House	5.53	12.2	39.1	11.8	8.2	6.0	20.6	8.9	3.7	41.9	11.4
Suffield	5.60	21.3	50.9	19.9	8.3	18.0	70.6	15.0	14.9	48.4	18.5
Whitecourt	5.71	16.7	41.9	12.8	6.5	19.2	11.5	11.1	11.9	93.0	19.5
OVERALL	5.48	14.5	41.1	14.7	7.3	10.8	25.2	12.5	6.0	55.3	14.8

[1] Alberta Environmental Stations 1978-1984 except for Calgary (1979-1984); CANSAP Stations 1978-1983.
[2] Ratio of measured to calculated specific conductance.

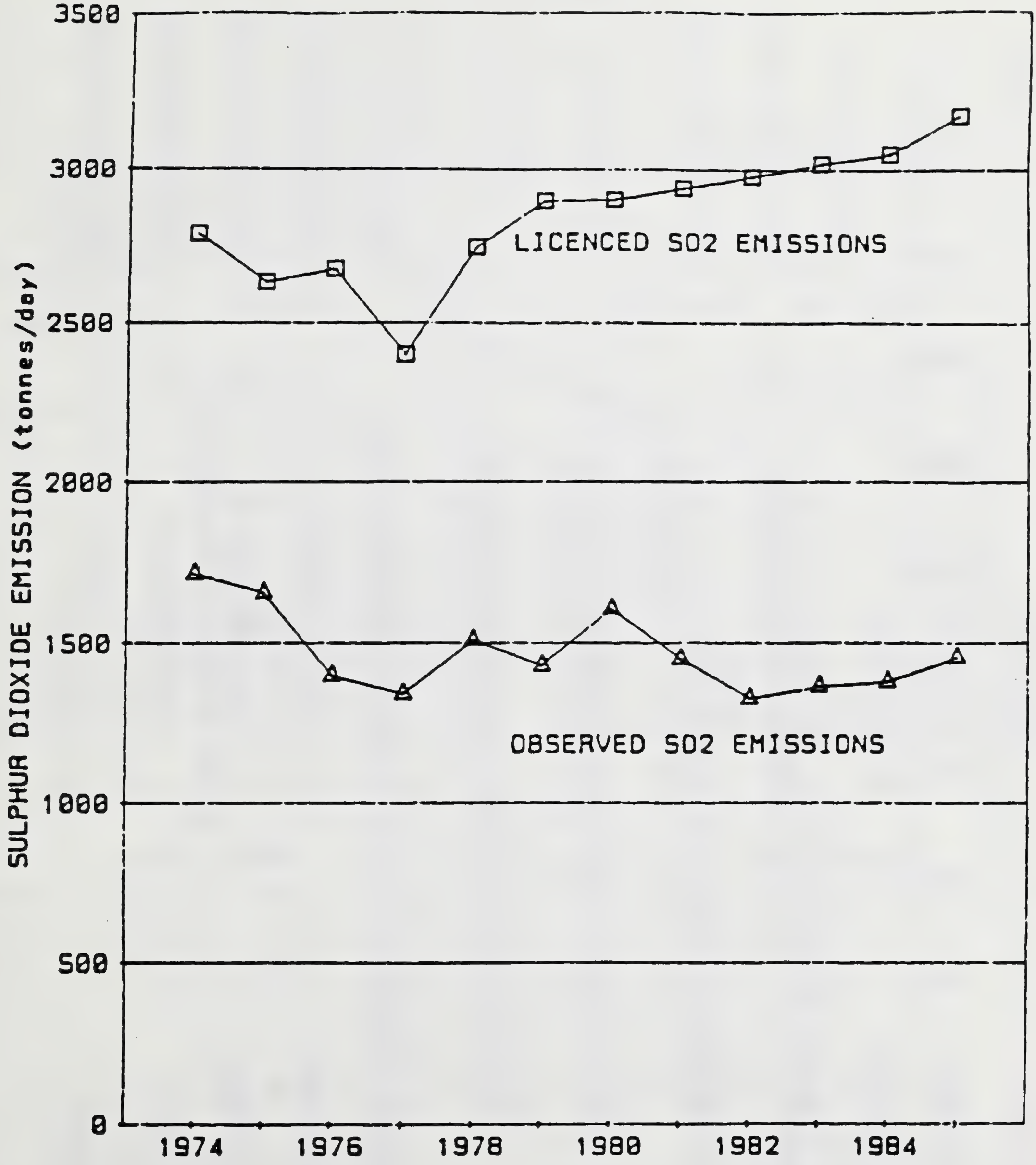


Figure 1. Summary of the trend versus licensed emissions of sulphur dioxide in Alberta.

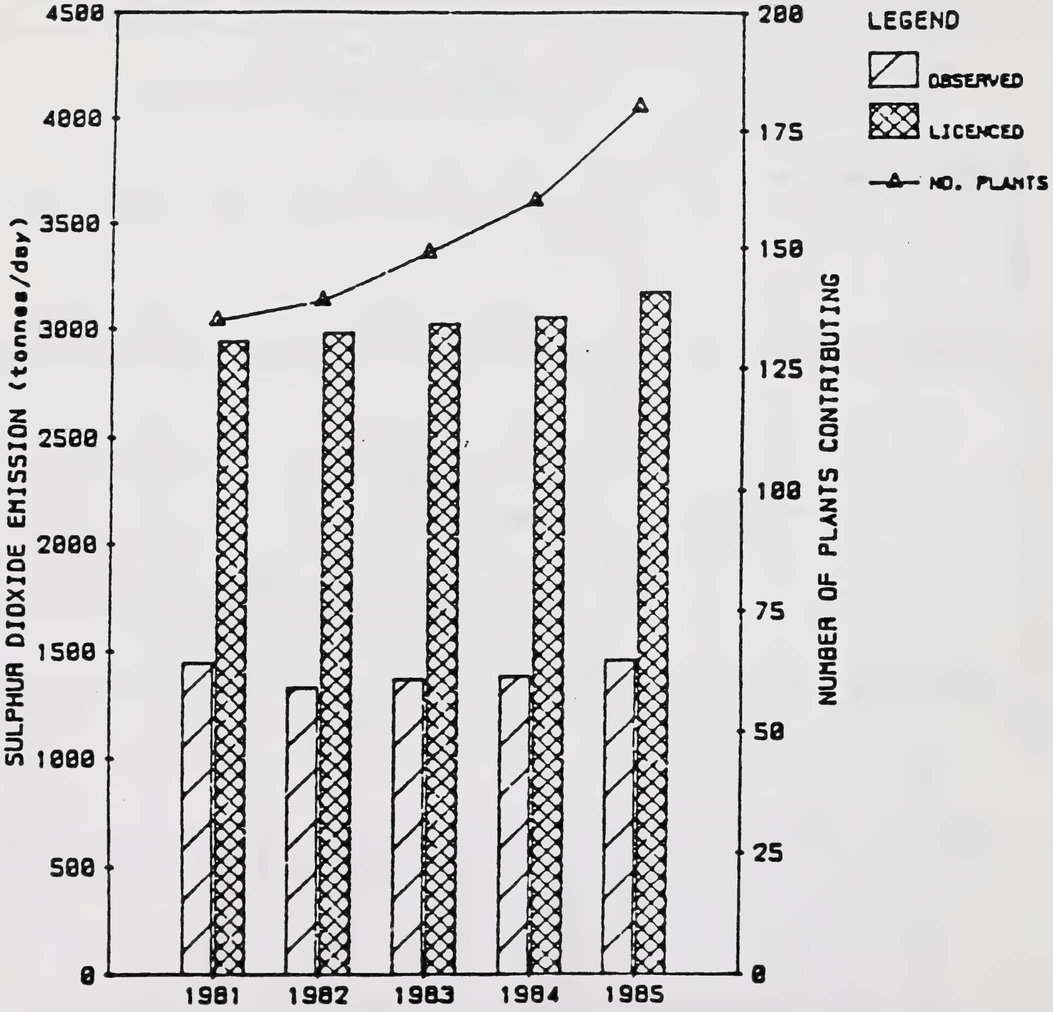


Figure 2. Summary of the trend versus licensed emissions of sulphur dioxide in Alberta given with the number of sulphur dioxide emitting plants.

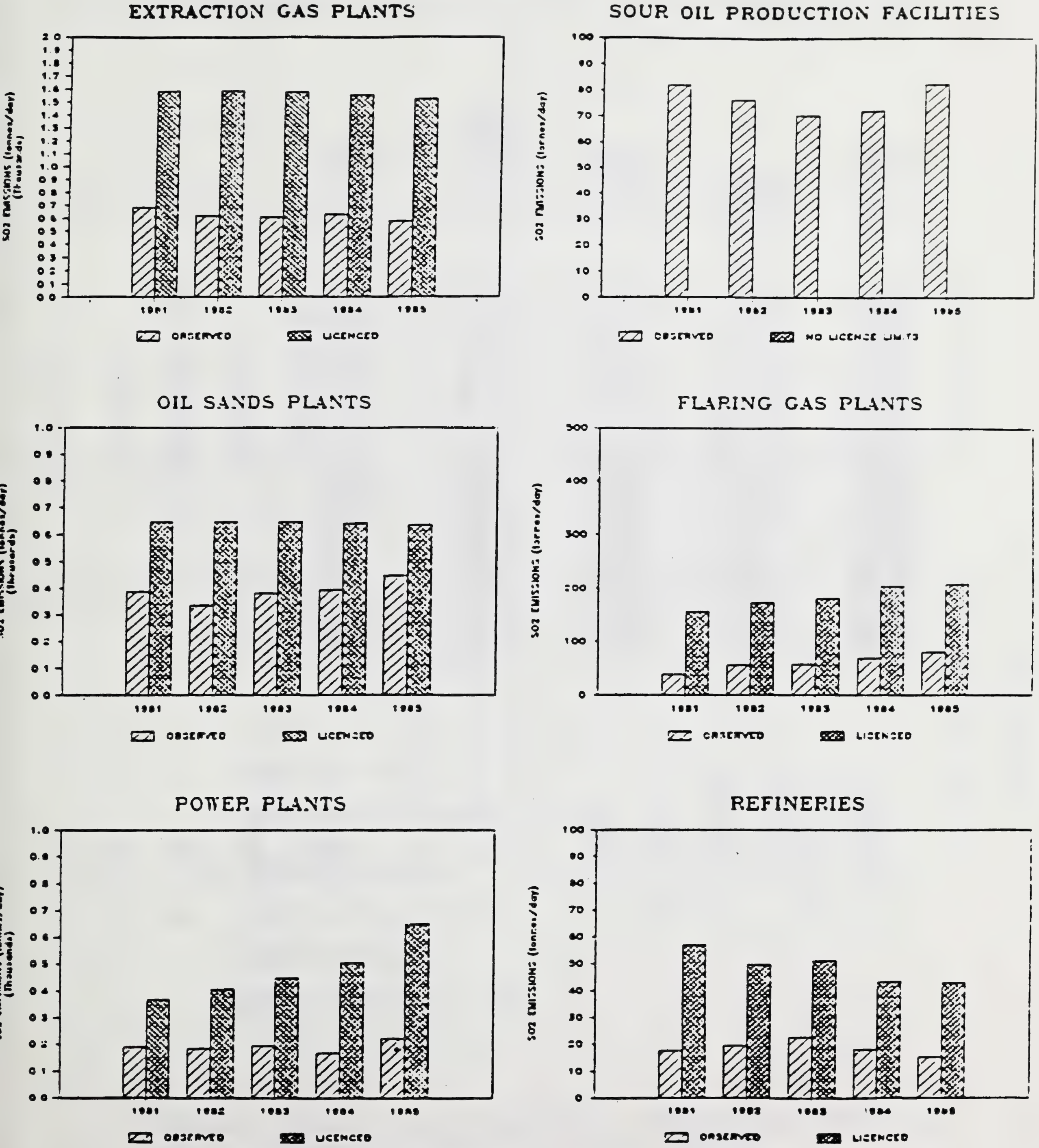


Figure 3. Comparison of observed versus licensed sulphur dioxide emissions and number of licensed sources in Alberta for the 1981-85 interval.

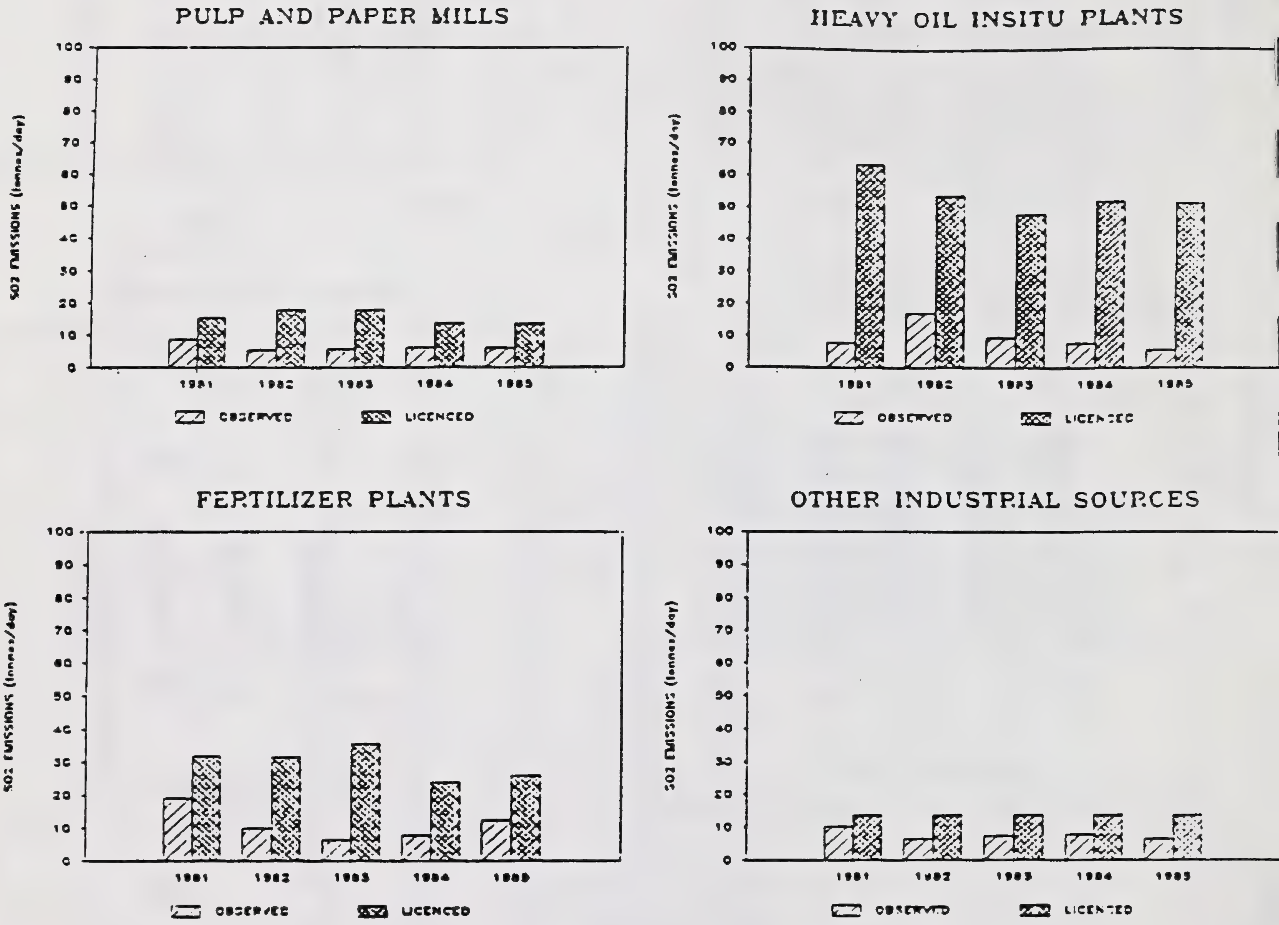


Figure 4. Comparison of observed versus licensed sulphur dioxide emissions from specific industrial categories in Alberta for the 1981-85 interval.

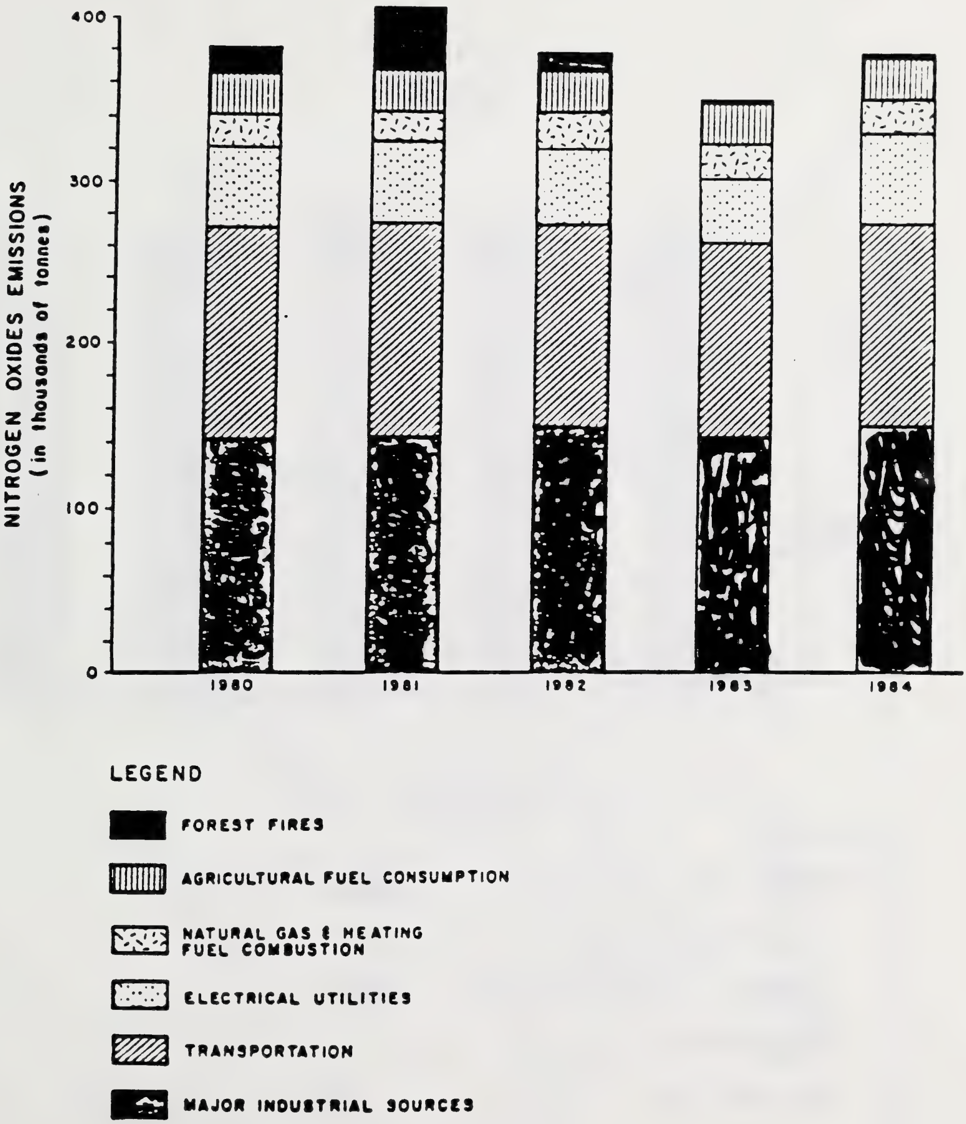


Figure 5. Trends in the nitrogen oxides emissions from 1980 to 1984 and contributing source categories.

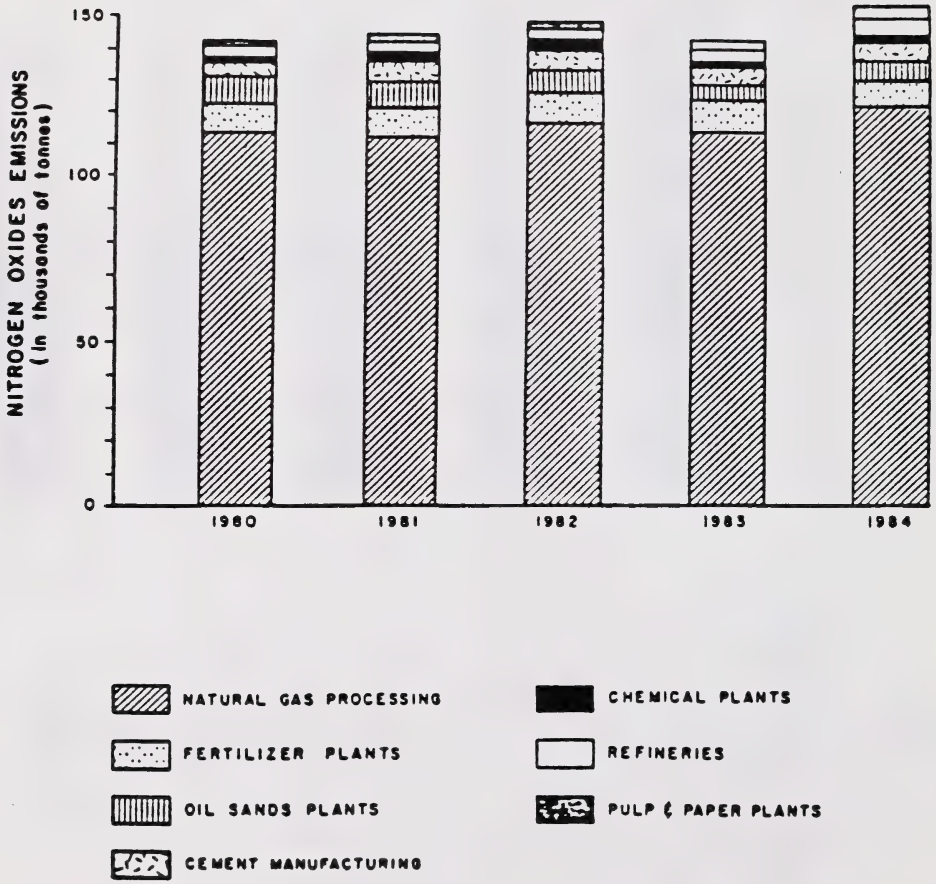


Figure 6. Trends in the nitrogen oxides emissions from 1980 to 1984 and contributing industrial categories.

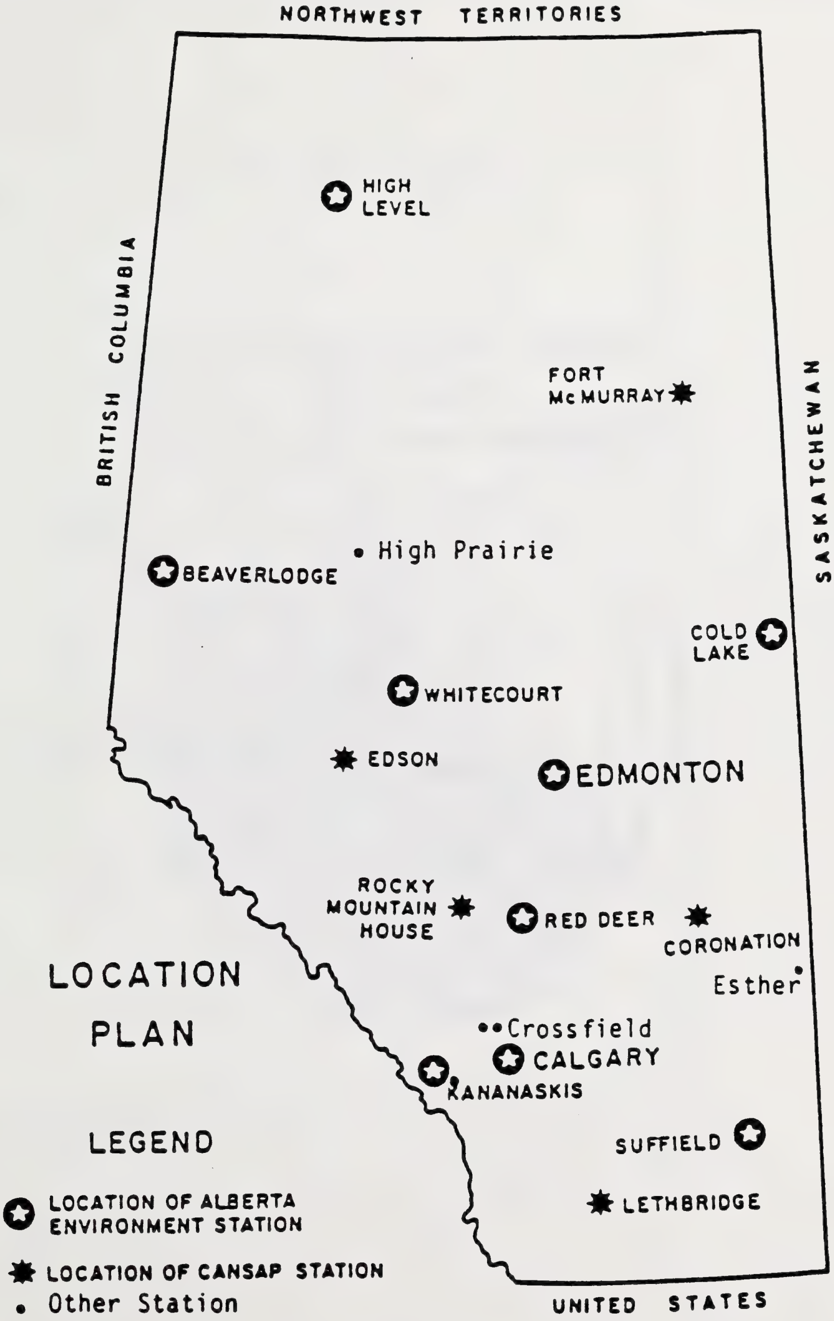
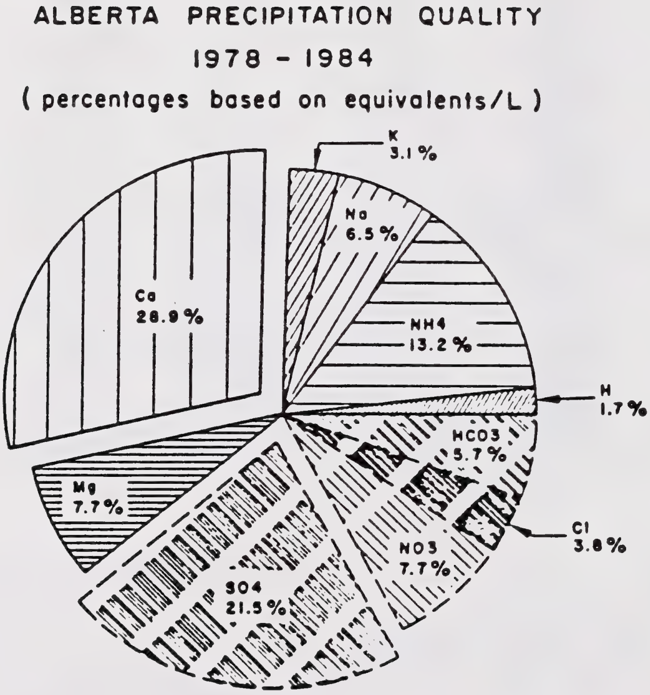


Figure 7. Map of Alberta giving locations of precipitation quality monitoring stations.



ALBERTA PRECIPITATION QUALITY
1978 - 1984
(percentages based on equivalents/L)

Figure 8. Pie graph of representative precipitation quality in Alberta.

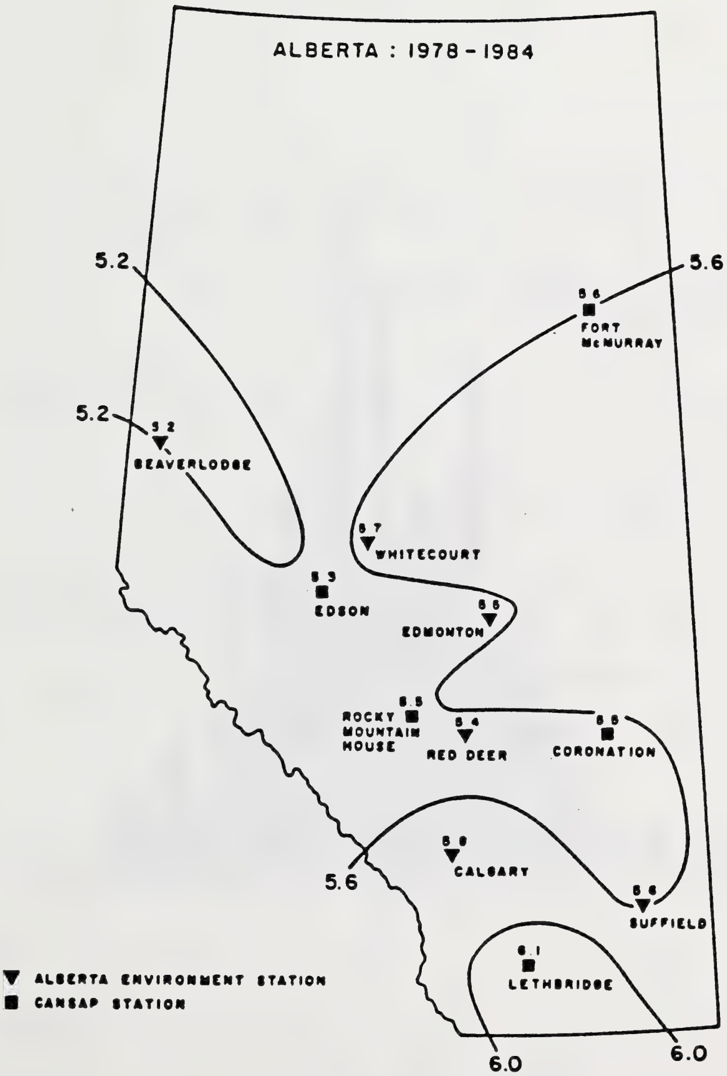


Figure 9. Map of Alberta giving spatial distribution of volume-weighted average pH of precipitation by region.

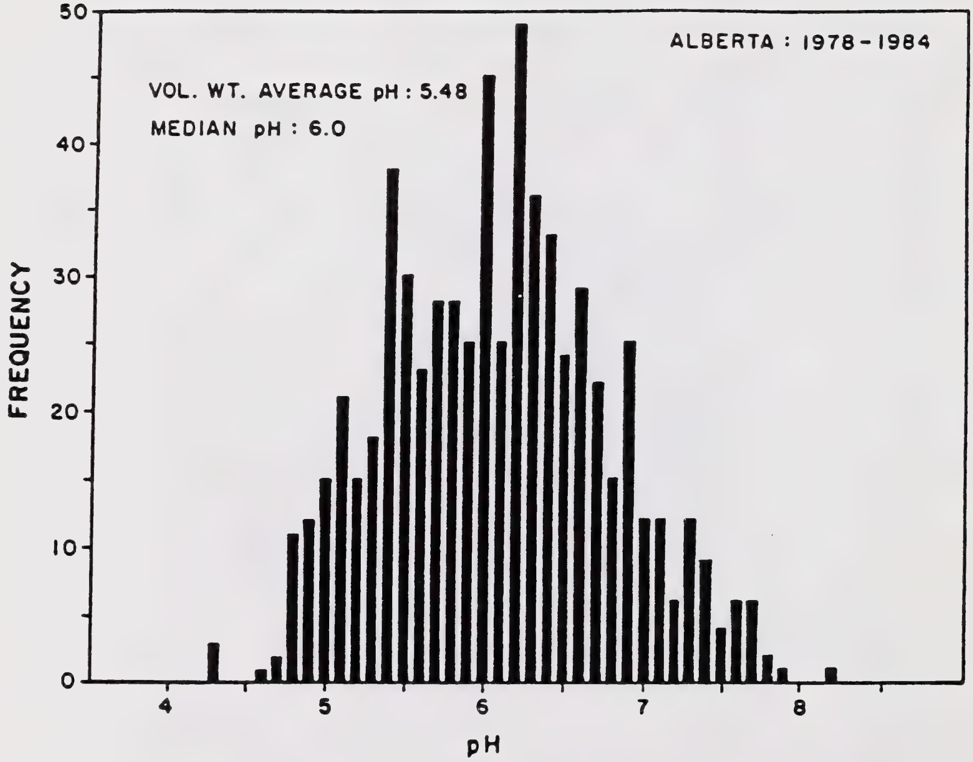


Figure 10. Frequency of precipitation pH for Alberta.

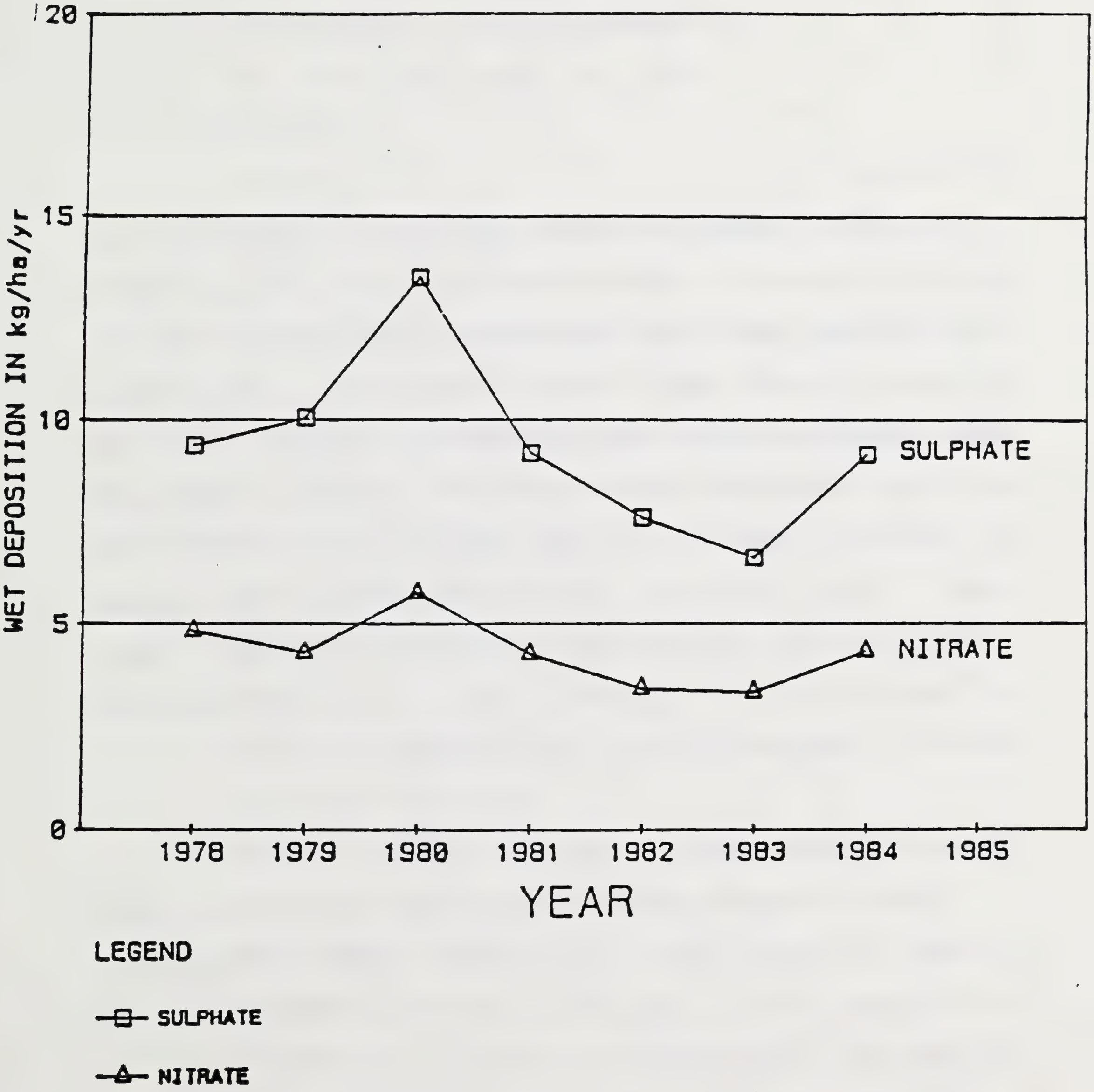


Figure 11. Plot of wet deposition of sulphate and nitrate in Alberta versus year.

LITERATURE REVIEW OF ACID FORMING EMISSIONS IN LIVESTOCK

M.G. Prior and A. Lopez

INTRODUCTION

Airborne pollutants from one or more sources can adversely affect human or animal health within a few feet or as far away as tens of kilometers from the origin. The effects may be localized or regional, national or international. Airborne pollutants are a highly diverse group of substances consisting of particles, aerosols, vapours, and gases of inorganic and organic substances. Examples of particulate air pollution observed in farming operations are soil and grain dusts. Aerosol pollutants associated with farming are the water droplets and pesticide mists seen during spraying operations. Vapours are gases of volatile substances such as motor fuels and paint solvents. Gases are substances such as propane.

Factors Affecting Uptake of Airborne Pollutants

Airborne pollutants enter the body through the respiratory tract. A number of factors affect the deposition, uptake and retention of inhaled gases, vapours, and particulates. Factors affecting the site of deposition of gases and vapours include:

a) water/lipid solubility,

b) physical/chemical properties of gas or vapour.

Factors affecting the uptake of gases and vapours include:

c) diffusion,

d) lipid solubility,

e) metabolism,

f) perfusion.

The deposition of particles in the respiratory tract depends on particle size. Generally, particles with a diameter of 30 to 5 microns are deposited in the nasopharyngeal region, particles with a diameter of 5 to 1 microns lodge in the trachea, bronchi or bronchioles, while particles of less than 1 micron in diameter pass to the alveoli. Factors that influence the retention of vapours and particulates include:

g) chemical transformation,

h) solubility,

i) matrix,

j) aerodynamic diameter,

k) site in respiratory tract,

l) clearance pathways.

Clearance pathways and rates may be affected by:

m) constitutional factors,

n) environmental factors,

o) pollutants,

p) drugs,

q) pre-existing disease.

Thus the site and deposition, retention and uptake of airborne pollutants is influenced by a number of physico-chemical and biological parameters.

Acid-forming and Other Airborne Pollutants

Acid-forming pollutants include the oxides of sulphur and nitrogen, as well as secondary pollutants such as ozone (United States-Canada Memorandum of Intent on Transboundary Air Pollution Interim Report, 1981). These acid-forming pollutants do not occur as the sole chemical compound in the ambient air. Rather, they occur in combination with other pollutants. This fact influences their effects on animals, for the sum of the effects of exposure to these pollutants may be additive, synergistic, or subtractive to their individual effects. Furthermore, the presence of naturally-occurring gases, such as ozone, may alter the toxicity of a particular pollutant. Expansion of industrialization and urbanization has contributed greatly to the rise in the incidence of pollution in the environment (Lillie, 1972). With this has developed a growing awareness of the potential for adverse human and animal health effects.

In 1982, Canada was the third largest producer of sulphur-in-all-forms (13%) and the second largest producer of elemental sulphur (18%). Domestic consumption accounts for only 22% of Canadian production of sulphur-in-all-forms. Therefore Canada has substantial volumes of sulphur available for export (Muir, 1984). The province of

Alberta lies over substantial reserves of sulphur, mostly in the form of sour gas.

Pollutants of Interest

Of concern are sulphur-containing and non-sulphur-containing pollutants and their possible effects on human and animal health. Airborne pollutants may be present as gases, particles, or aerosols. In these forms, the pollutants might be predicted to have health effects, especially on the respiratory tract, skin, and eyes. People in a number of agricultural communities in Alberta close to sulphur extraction gas plants, who have been personally affected by emissions, demonstrate an extremely high level of concern for the effects of gas plant pollution (Environment Conservation Authority, 1973). Well blowouts may release hydrogen sulphide and other toxic substances into the atmosphere. Public concern has shifted to include the perception that a number of as yet unspecified health effects may be due to, or exacerbated by, sulphur-containing emissions. These concerns are not limited to livestock, but include wildlife and human health. In addition, the effects of non-sulphur-containing compounds, such as the nitrogen oxides, ozone, ammonia, carbon monoxide, and dusts are important to livestock health and production.

Sources

The sources of these sulphur-containing and acid-forming emissions are fourfold:

(a) emissions from normal industrial operations,

(b) emissions from malfunctioning industrial operations,

(c) catastrophic events, for example, well blowouts,

(d) natural sources, for example, sulphur springs, or anaerobic decay of biological materials.

The particular constituents present in emissions from each of these sources will differ, and often vary between sources in the same category.

Unlike many airborne pollutants, sulphur and its compounds occur naturally. It should be noted that sulphur is essential for plant and animal life and is present in vital tissues (National Research Council of Canada, 1977).

Sour Gas

Sour gas is a trivial term for natural gas that contains varying concentrations of hydrogen sulphide. Natural gas is a complex mixture of aliphatic, alicyclic and aromatic hydrocarbons, and, in the case of sour gas, compounds containing sulphur. Predominant hydrocarbons are generally low molecular weight aliphatics such as methane, ethane and butane. Alicyclic and aromatic hydrocarbons are predominantly found in the condensate fraction. Gaseous and volatile sulphur compounds found include hydrogen sulphide, carbonyl sulphide, carbon disulphide, methyl-, ethyl-, and propyl-mercaptans. Generally, hydrogen sulphide is the major sulphur-containing constituent.

The chemical composition of sour gas varies between natural gas deposits. Some sour gas wells contain only low levels of hydrogen sulphide, while other wells, drilled for the commercial value of sulphur, contain hydrogen sulphide as the predominant gas. The chemical analysis of a sour gas well that was involved in a blowout episode is listed in Table 1. The recovery and processing of sour gas may give rise to sulphur dusts, and to oxidation products such as the sulphur oxides. A bibliography of publications on the toxicity of hydrogen sulphide and other sulphur-containing compounds has been published (Lee et al, 1985, 1986; Lee and Prior, 1986). The published literature pertaining to the toxicity for farm animals of sulphur-containing and other compounds associated with sour gas and acid-forming pollutants is discussed in this paper.

REVIEW OF TOXICITY FOR FARM ANIMALS

The compounds to be reviewed for their possible toxicity for farm animals are carbon disulphide, carbonyl sulphide, ethyl sulphide, methyl sulphide, hydrogen sulphide, methylmercaptan, ethylmercaptan, propylmercaptan, nitrogen oxides, ozone, sulphur, and sulphur dioxide.

Carbon Disulphide

Carbon disulphide is a colourless, volatile liquid with a sweet aromatic odour reminiscent of chloroform. The technical product is a yellowish liquid with a disagreeable odour of decaying radishes (World

Health Organization, 1979). Sources are viscose rayon manufacture, coal gas formation, industrial solvent, and sour gas. It evaporates at room temperature, and its vapours are 2.62 times heavier than air. In dogs, cats, and rats, carbon disulphide induces excitement followed by drowsiness associated with tremors and ataxia, loss of conditioned reflexes, and altered disposition after prolonged exposure (Alpers and Lewey, 1940; Dietzmann and Laass, 1977; Ferraro et al, 1941; Lewey et al, 1941). Peripheral nerve degeneration, especially the branchial plexuses and sciatic nerves, have been observed in the dog and rat (Haltia and Linnoila, 1978a, 1978b). Increased thickness of the aortic wall was observed in rats following prolonged exposure (Grodetskaya et al, 1979).

Carbon disulphide has an enhancing effect on atherogenesis induced by cholesterol in rabbits and rats (Wronska- Nofer et al, 1978, 1980). Altered endocrine function has been reported in female rats exposed to relatively low concentrations of carbon disulphide, with increased thyroid activity and altered oestrus cycles (Kramarenko et al, 1969). Chronic interstitial nephritis has been described in rabbits following prolonged inhalation exposure (Cohen et al, 1959; Cuccurullo et al, 1978). Carbon disulphide is metabolized to carbonyl sulphide and sulphur radical by hepatic cytochrome P-450 and associated microsomal mono-oxygenase enzymes (DeMatteis and Seawright, 1975).

Carbonyl Sulphide

Carbonyl sulphide is a pungent, colourless gas. It is a by-product of the oxidative metabolism of carbon disulphide (Daivi et al, 1975), and is metabolized by hepatic carbonic anhydrase (Chengelis and Neil, 1980).

Ethyl Sulphide (Diethyl Sulphide)

Ethyl sulphide is a liquid with a garlic-like odour. It occurs in trace amounts in petroleum deposits and may impair respiration and irritate the eyes (Selyuzhitskii and Timofev, 1972).

Methyl Sulphide (Dimethyl Sulphide)

Methyl sulphide is a colourless liquid with a disagreeable odour, and occurs in small quantities with methylmercaptan in gas. Larger quantities inhibit carbonic anhydrase (Braker and Mossman, 1971; Schwimmer, 1975).

Hydrogen Sulphide

Hydrogen sulphide is a colourless gas having the characteristic odour of rotten eggs at low concentrations. The gas occurs naturally in coal, natural gas, oil, volcanic gases, sulphur springs, and lakes; it is a product of the anaerobic decomposition of sulphur-containing organic matter, such as manure pits. It is also a by-product of the production of coke, manufacture of gases from coal, production of viscose rayon, the kraft process for producing chemical pulp from wood, and desulphurization of sour natural gas. The occupational hazards of exposure to hydrogen sulphide are well known (National Research Council of Canada, 1981), and the National Institute for Occupational Health and Safety (1977) lists 73 occupations of approximately 125,000 workers with potential for exposure to the gas. In and around Rotorua, New Zealand, ambient concentrations have exceeded 1 ppm at one specific site (Thom and Douglas, 1976), and at another site 0.05 ppm was exceeded over 35 percent of the winter time, or 20 percent of the time in summer (Rolfe, 1980).

Potential for Exposure

The majority of environmental, as opposed to industrial, exposures are to hydrogen sulphide together with other sulphur containing compounds. There appears to be no recent data on ambient concentrations of hydrogen sulphide in the published literature. Elevated ambient concentrations have been recorded on several occasions. One was in the Great Kanawha River Valley in West Virginia in 1950, with a reported maximum concentration of 410 ppb (West Virginia Department of Health, 1950); another in Terre Haute, Indiana in 1964, with a maximum concentration above 460 ppb (U.S. Public Health Service, 1964). General symptoms of malaise, irritability, headache, insomnia, and nausea were reported by members of the exposed population.

Gas well blowouts can also be a cause of elevated concentrations of hydrogen sulphide. This happened in the Camrose area in 1973, the Drayton Valley-Lodgepole area in 1977 and again in 1982, the Claresholm area in 1984 (New Norway Scientific Committee, 1974; Energy Resources Conservation Board, 1978; Lodgepole Blowout Inquiry, 1984; Alberta Environmental Centre, 1986). The second Lodgepole episode was the most extensive; the highest concentration recorded away from the blowout site was 23 ppm at a location 13 km southeast of the blowout site. The maximum concentration at two towns 20 km to the east and northeast was 14.5 ppm, and the maximum concentration at Edmonton, some 140 km to the east-northeast, was 0.5 ppm (Lodgepole Blowout Inquiry, 1984).

Effects on Farm Animals

The results of experimental exposure of cattle, goats, pigs and poultry to hydrogen sulphide are summarized in Table 2. The two major sources of exposure for livestock are manure gas and sour gas operations. Deaths have been reported in pigs and cattle following the emptying of slurry (manure) tanks, when agitation releases the toxic gases (McAllister and McQuitty, 1965; Lawson and McAllister, 1966; Bjorklund et al, 1972). Four groups of four adult female goats (50 - 100 kg bodyweight) were exposed for four continuous days to 0, 10, 50 or 100 ppm hydrogen sulphide. Feed and water consumption were reduced during the first two days of exposure in some goats of the gas exposed groups; however, most returned to normal by the fourth day of exposure. One goat in each exposure group developed pyrexia, and one goat at 100 ppm died after 19 hours of exposure. All of the exposed goats developed irritated eyes and coughs, although these often abated by the fourth day; and, the heart rate increased slightly (Hays et al, 1972).

The respiratory response to acute inhalation of hydrogen sulphide was studied in male White Leghorn chickens. Low concentrations (500 ppm) for 30 minutes had no effect on ventilation. There was a slow rise and fall in respiratory frequency and tidal volume in birds exposed to 2000 ppm, and a sharp rise and fall in birds exposed to 3000 ppm. All birds exposed to 4000 ppm died within 15 minutes (Klentz and Fedde, 1978).

Methylmercaptan (Methanethiol)

Methylmercaptan is a colourless gas with an odour of decaying cabbage, and is highly flammable. It is found in some natural gas deposits and in coal tar. It is recovered from various petroleum distillates, and occurs in small quantities in vegetables such as garlic and onion. It is found in cabbage following microbial degradation of methionine and L-homomethionine. Methylmercaptan evolves into a toxic fume when exposed to heat and fire and it quickly oxidizes to sulphur oxides. It also reacts with water, steam, and acids to form toxic flammable vapours. In rats, mice and primates, it depresses the central nervous system, causes alveolar hemorrhaging and muscular weakness. At low levels, it induces some hematological and minor lung or brain effects. Methylmercaptan is a normal intermediate in the metabolism of sulphur-containing amino acids, and is used in the synthesis of new methionine or protein (Ljunggren and Norberg, 1943; Sandage, 1961; Horiguchi, 1960; Zieve et al, 1974).

Ethylmercaptan (Ethanethiol)

Ethylmercaptan is a colourless, highly flammable liquid, with a penetrating garlic-like odour. It occurs in natural gas, petroleum distillates and coal tar, as well as in vegetables such as cabbage. Because it exists as a liquid at lower temperatures and as a gas at higher temperatures, all routes of exposure should be considered. In rats and rabbits it acts as an irritant, depresses the central nervous system, and may cause muscular weakness, cardiovascular disorders, and changes in light adaption and the hematopoietic system (Fairchild and Stokinger, 1958; Wada, 1959; Blinova, 1964; Shibata, 1966; Cession-Fossion et al, 1968; Selyuzhitskii and Timofev, 1972).

Propylmercaptan (Propanethiol)

Propanethiol is a clear liquid with a very unpleasant odour. It is of relatively low toxicity.

Nitrogen Oxides

The nitrogen oxides present in the air are produced by natural processes including lightning, volcanic eruptions and bacterial action in the soil, as well as by man-made activities. It has been estimated that the annual, natural global emissions of these oxides far exceeds emissions generated by man-made activities (Robinson and Robbins, 1972). The major source of man-made emissions is the combustion of fossil fuels.

Effects on Farm Animals

Nitrogen oxide, released from silos as seepage at concentrations in the range of 115 to 151 ppm (216 to 284 mg m^{-3}) is lethal for poultry, pigs, calves, and man. Initial symptoms included coughing, increased respiratory and pulse rates, anorexia, salivation, and mouth breathing (Anon, 1959a; Anon, 1959b). Methemoglobinaemia, dilation of blood vessels, and decreased blood pressure were also reported (Anon, 1959a). Cases similar to "silo filler's disease" of man have been reported in farm animals. Pigs inhaling gas containing 250 to 310 ppm nitrogen dioxide died in 21 to 72 minutes, with pulmonary alveolar oedema and hyperaemia; those surviving did not develop the bronchitis fibrosa obliterans seen in man (Giddens et al, 1970). In cattle, experimental nitrogen dioxide exposures resulted in apneoa, progressive dyspnoea, lacrimation, excessive salivation, grunting, reduced feed and water consumption, emaciation, and dehydration.

Other changes included methaemoglobinaemia, necrosis of skeletal muscles, pulmonary edema, broncholitis, infarction, and emphysema (Cutlip, 1966).

Ozone

Ozone concentrations of 2000 ug m^{-3} (1.0 ppm) or less with exposure periods of up to 24 hours produced numerous morphological changes in the lung parenchyma in several laboratory animal species. With exposures from six to ten months, pulmonary lesions including emphysema, atelectasis, focal necrosis, bronchopneumonia, and fibrosis have been reported (World Health Organization, 1978).

Sulphur

The feeding of 30 g of sulphur daily to cattle had no observable adverse effects (Steyn, 1934). However, deaths have been reported following ingestion of 180 and 240 g (McFarlane, 1952). Horses have been killed by 240 to 420 g (Percy, 1910), and continued feeding of sulphur at a level of 2% in the feed was harmful to growing chicks (Cabrera, 1941).

Sulphur Dioxide

Sulphur dioxide is used in the manufacture of sulphuric acid, sodium sulphite and other chemical processes. Large quantities are used in refrigeration, bleaching, fumigating, and preserving (Sulfur dioxide, 1963).

Sulphur dioxide is an oxidation product of hydrogen sulphide. It can be oxidized in the air to form sulphuric acid and through reaction with other pollutants, sulphates. Sulphur dioxide and sulphur trioxide are the two sulphur oxides of greatest concern. The major pollution events in the Meuse Valley, Belgium, in 1930, and in London, England, in the winter of 1952-53 were caused by meteorological inversions; and sulphur dioxide was believed to have been the major contributor to the health effects in livestock and human beings. Respiratory distress was relieved in affected cattle by removal to unaffected areas or oxygen therapy. Deaths in cattle in the London episode were attributed to a combination of sulphur dioxide, sulphuric acid mist, and other toxic agents (Firket, 1931, 1936; Anon, 1953; Cullumbine et al, 1954).

Effects on Farm Animals

Young pigs exposed experimentally to 5, 10, 20, or 40 ppm sulphur dioxide for eight hours developed slight eye irritation and salivation, with nasal discharge and altered respiration developing at higher concentrations. Hemorrhage and emphysema occurred at the highest concentration. At 158 days post-exposure, pulmonary fibrosis was found in pigs exposed to 20 or 40 ppm (O'Donoghue and Graesser, 1962). In a 90 day double reversal feeding trial, cows fed a ration of mixed grain, corn silage, and either uncontaminated or contaminated (from sulphur dioxide emissions into the atmosphere from an industrial plant) alfalfa hay, did not develop significant changes in milk production, body weight, digestibility of the rations, palatability, or urine pH (Cunningham et al, 1937).

RELATIVE TOXICITY OF THE CONSTITUENT COMPOUNDS

The relative toxicity of some of the compounds that might occur during the recovery and processing of sour natural gas deposits are listed in Table 3. The current standards for exposure of human beings to some of these compounds is summarized in Table 4. It should be noted that these values are based on an eight hour exposure period, equivalent to a typical industrial working day, and that there are no equivalent values for livestock. There is no similar information for livestock pertaining to regulatory exposure limits. However, there is some information on the effects in laboratory animals, livestock and poultry which were exposed to hydrogen sulphide concurrently with different airborne pollutants, such as ammonia, carbon dioxide, or sulphur dioxide, or other compounds such as ethanol. This is summarized in Table 5.

REVIEW OF FIELD DATA

There are a number of published reports on the effects of emissions containing sulphur compounds on livestock. It must be stressed that these reports represent the sum of the individual effects of all the airborne pollutants to which the animals were exposed. These pollutants include both sulphur- and non sulphur-containing compounds. It is difficult, if not impossible, to replicate such complex mixtures under the more controlled laboratory or field conditions.

Effects of Emissions from a Gas Plant on Livestock

The direct, long term (1 to 3 years) effects on cattle, hogs and chickens of emissions from the Waterton gas plant have been studied (McKinnon et al, 1977). Groups of animals were maintained under natural farm conditions in both emission (high concentrations of sulphur compounds) and control (low, but not necessarily zero concentrations) zones. There were no differences in the general health of the animals studied.

Gas Well Blowout near Camrose, 1973

Very few reports were received by practitioners or others in the area or by the Veterinary Laboratory during or subsequent to a gas well blowout in September 1973 near Camrose. One herd of cattle was reported to have watery eyes and noses. There were no mortalities, and no further problems occurred. One herd of pigs kept in a building was reported to have been affected by diarrhea which cleared by itself in two days with no mortalities. Tissues from animals which died at the time of, or shortly after, the gas exposure, were sent to the laboratory. The owners were concerned that hydrogen sulphide gas may have killed the animals. Cattle specimens from six areas and swine specimens from three areas were examined. Two of the cases in cattle were diagnosed as bloat and three as pneumonia. One animal was undiagnosed, mainly as a result of post-mortem decomposition. One of the pigs examined had pneumonia, one acute enteritis, and one streptococcal septicaemia (New Norway Scientific Committee, 1972).

Pilot Study in West Central Alberta

A pilot study was conducted in west central Alberta. Two dairy and two beef farms served as test sites. Analysis of forage, as well as feed and grain samples taken from the farms indicated that the homegrown crops tended to be low in selenium, sulphur, zinc and copper, and that soil samples were deficient in selenium and sulphur. An estimate of sulphur deposition in the area was approximately 6 kg/h.

The low sulphur content in soil would suggest that trace element deficiencies in the feeds of the area were not due to deposition of sulphur, but rather to naturally low levels of the elements in the soils. It was, therefore, necessary to supplement the rations with trace minerals in order to maintain health and productivity. It was also apparent that it was necessary to ensure that the supplementation was ingested by the cattle. The pilot study did not provide, nor was it designed to provide, information on the effects of inhalation of sulphur emissions on livestock (Prior et al, 1982).

Lodgepole Blowout - Pembina Area Sour Gas Committee

A study was commissioned by the Pembina Area Sour Gas Exposures Committee to study the impact of the Lodgepole blowout on the areas immediately surrounding the incident. Approximately 90 livestock producers in the Lodgepole-Cynthia area were interviewed. An area close to Bonnyville served as the control area. The identification and evaluation of the problems noted in livestock was carried out through analysis of information gathered by:

(a) personal accounts, including written comments on the questionnaire by PASGEC members,
(b) the WIN Consulting Study,
(c) the published H_2S and SO_2 literature,
(d) consultation with veterinarians, animal nutritionists, and agricultural engineers.

As stated in the report: "Because the numbers of livestock producers surveyed is not large from a statistical analysis point of view, and responses were recorded on a per farm rather than per animal basis, numbers in most symptom categories were too small to enable analysis for association with the blowout."

Of those involved in agriculture in the blowout areas, specifically in the Lodgepole area to the west of Drayton Valley, more than half of those who had some form of livestock indicated that the blowout had had some effect on their livestock. This compares to an almost insignificant number who indicated that the blowout had had specific effects of crop production. A severity rating scale, from 1 (very severe) to 8 (cannot remember), was used for the agricultural questions. The increased incidence of several conditions during the blowout episode was reported, and these are summarized in Table 6.

In addition, several producers reported that animals did not eat well during the blowout. The most commonly mentioned problem in Area 1 was calving; 60 percent of all farmers who attributed any of their livestock problems to the blowout identified calving as a problem. In addition, a veterinarian reported that there appeared to be an increased number of cows requiring assistance at parturition. One herd of Holsteins, part of the Dairy Herd Improvement Program of Alberta Agriculture, in Area 1, had been yielding 18,000 to 19,000 litres of milk monthly from May to the time of the blowout. During the blowout period, the milk yield for October was 15,200, for November, 14,400 and for December, 14,200 litres. Cattle and swine were reported to be returning to heat during the blowout, having apparently bred previously (Pembina Area Sour Gas Exposure Committee, 1983).

Lodgepole Blowout - Agriculture Submission to ERCB Inquiry

Laboratory submissions from the review area were monitored until April 30, 1983. No evidence was found that hydrogen sulphide caused or contributed to disease in animals. No effect on pregnant animals could be determined from an examination of aborted fetuses. A specific comparison of congenital defects in cattle revealed no differences in diagnosis between the review area and the rest of Central Alberta Province (Government of Alberta, 1983).

Lodgepole Blowout - Alberta Environmental Centre

A gas well being drilled by Amoco Canada Petroleum Limited in the Lodgepole-Drayton Valley area blew out of control on October 17, 1982. This resulted in the emission of large quantities of natural gas, hydrocarbon condensates and sulphur gases into the atmosphere over a nine week period. A study was undertaken to determine whether the blowout emission affected the activity of five enzymes in exposed cattle. These enzymes were superoxide dismutase, glutathione peroxidase, glucose-6-phosphate dehydrogenase, acetylcholinesterase, and aspartate aminotransferase. Levels of the activities of these enzymes may serve as an indicator of biochemical (metabolic) reaction to exposure to sulphur compounds.

Blood samples were obtained from animals at each of ten sites at various distances and directions from the blowout site during the emission episode and on three occasions subsequent to its cessation. Some statistically significant biochemical perturbations were observed; in all cases, however, the changes appeared to be transient and reversible. The fact that it was possible to obtain information on the activities of the five selected enzymes from only 14 of the original 50 known exposed animals on four farms for the one year period of this investigation makes interpretation of the enzyme assay results more difficult.

Post-Lodgepole Blowout - Alberta Agriculture Review

A study was conducted in June, 1985 to evaluate the long term effects of the Lodgepole blowout. The study was a subjective evaluation of the concerns expressed by livestock producers based on their records and feelings about the problems which occurred during and after the blowout. Twenty-five beef cow-calf producers, two swine and one dairy producer were interviewed for the study.

The cow-calf producers were concentrated in the Violet Grove area since it was the nearest area populated with livestock in the sulphur deposition zone as outlined by the ERCB reports. Because there was no reference data, nor herds with complete records within the area, it was difficult to establish whether the problems may have been caused by herd management, weather, or by complications from the blowout. A work sheet was developed to establish cow herd performance for the years 1980-1985. Areas of concern included:

(a) numbers of calves born alive,
(b) stillborn and defective calves,
(c) scouring problems,
(d) calf growth through the following year.

In the cow herds, breeding performance was evaluated by attempting to tabulate the number of dry cows or open cows and by examining the number of late calves which occurred in the herds under study. The problems which cow-calf producers identified were not consistent throughout the group.

In an attempt to avoid bias in the evaluation of potential problems, all the major producers within the Violet Grove area were contacted as well as selected producers throughout the Drayton Valley area. Several producers had good records of their herd's performance. However, there were no record of other variables that could have changed during the study period. These included weather conditions, fly problems, feed analysis and management changes.

More problems were identified during 1983 and in the period following the blowout (Table 7). Most of the problems have subsided, although there were still concerns about the performance of replacement heifers exposed as calves during the blowout. These heifers do not appear to have grown and developed as well as producers had expected. Also, these heifers do not appear to be milking as well as they should be according to several publishers.

In the hog operation, numerous problems occurred during and immediately following the blowout. The number of pigs/sow/year definitely decreased for the two years following the blowout. Some of the gilts that were kept during that period of time have had to be culled because of low performance.

In general, most livestock producers felt that there were few long term effects on the mature livestock within the area. The majority of the problem animals have now been culled, and herd performance seems to be returning to levels prior to the blowout. On several farms, management practices have been changed to include trace mineral supplementation with copper, zinc, and selenium to help overcome the problem of weak calves. Growth rates in young stock appear to be back to normal. There are some producers who still have concerns about the development of the replacement stock which was affected by the blowout. Winter kill in legumes has been a problem, however, weather conditions in many areas of the province have been unfavourable for overwintering of legumes.

This report is subjective in nature since there is no concrete evidence to support many of the problems described or baseline studies to work from (Harris, 1986).

Sour Gas Well Blowout - Claresholm

On September 24-28, 1984, a gas well known as Drummond et al., Claresholm 6-30-12025 blew out of control. A total of 195 measurements of atmospheric concentrations of hydrogen sulphide in the area surrounding the well were made by Alberta Environment and the Energy Resources Conservation Board. The mean concentration over the four day period was 0.51 mg m^{-3} ± 0.80, with a range of 0.014 to 4.90 mg m^{-3}. Staff from Alberta Agriculture and AEC conducted an investigation into possible effects of the well emissions on livestock health. These began September 25, 1984 and continued into December, 1984. A total of sixteen farms were visited.

General complaints included irritation of ocular and respiratory membranes, respiratory disease (pneumonia), reduced exercise tolerance, and reproductive failure. The investigation team concluded that in several farms, up to a 4 km radius from the wellsite, the emissions from the well probably caused transient ocular and respiratory irritation in livestock, primarily horses and cattle. Irritation of sensitive membranes may also have occurred in livestock more distant from the wellsite, but this was probably not a significant factor. On one farm approximately 2 km northeast of the wellsite, there was reasonable evidence to conclude that the emissions may have produced a transient upper respiratory toxicosis in feeder cattle. This may have reduced the feeding performance of these animals and extended the feeding interval before slaughter. A second producer on a farm approximately 2 km east of the wellsite reported reproductive failure, loss of weight and condition and stamina in horses. These claims could not be well documented. However, it could be possible that well emissions may have had a transient effect on exercise tolerance in these animals. Another rancher observed reduced exercise tolerance in his horses. The field investigation could not support or refute the claim. A few of the other farms in the surrounding area also reported transient ocular and nasal irritation in the animals; but they did not report any reduction in exercise tolerance, condition or reproductive performance.

Overall, no consistent pattern of animal disease could be identified on farms located in the area surrounding the Drummond 6-30 well. Transient ocular and nasal irritation, some degree of reduced exercise tolerance, and, in one case, a respiratory condition could reasonably be attributed to exposure to emissions from the well, particularly on farms closest to the wellsite. Other livestock health problems reported by producers in the area could not be directly related to emissions from the well. The investigation team was able to find sufficient evidence to relate transient health problems on one farm to emissions from the well (Alberta Environmental Centre, 1986).

Experimental Studies - Goats and Cows

Respiration frequency decreased only in goats exposed to 100 ppm hydrogen sulphide for four days. Feed and water intake were reduced at all levels of hydrogen sulphide exposure. Plasma cortisol increased in goats exposed to 50 or 100 ppm and returned to near normal after four days of exposure. Heart rate and blood pressure changes were transient if present.

A decrease in respiration rate with exposure to 100 ppm hydrogen sulphide could have been due to the irritant effects of sulphide in the air passages resulting in pulmonary odema or irritant effects of the sulphide on pulmonary chemoreceptors in the airways or lungs, or the effects in the brain centres regulating respiration. The sites of action of hydrogen sulphide in the goat were not distinguished in this study.

Exposure of three lactating dairy cows to 20 ppm hydrogen sulphide for a three week period did not affect their feed intake, milk production, or heart rate. Slight lacrimation suggested some eye irritation during the same period. Although reports in the literature strongly suggested that exposure of cows to low levels of hydrogen sulphide for extended periods of time would be harmful, the present study indicated that exposure to 20 ppm for three weeks did not affect milk production. Only slight lacrimation was observed (Hays, 1972).

Experimental Study - Calves

Thirty-six steer calves averaging 215 kg liveweight were exposed to hydrogen sulphide in enclosed chambers for a continuous period of seven days. Exposure to 20 ppm hydrogen sulphide for one week apparently caused permanent tissue damage to the cornea. At 150 ppm, hydrogen sulphide induced severe corneal opacity and rupture of the eye appeared possible toward the end of the exposure period. Epistaxis was prominent in exposures at 150 ppm. Hydrogen sulphide at 20 and 150 ppm reduced mean weekly feed consumption. Water intake was also reduced at the higher concentration. Respiration rate was slightly increased at 20, and reduced at 150 ppm (Nordstrum, 1975).

Experiment - Effects of High Dietary Sulphur on Cattle

Because of the potential antagonism of sulphur to selenium and copper, there was concern that high sulphur intake resulting from industrial source deposition might interfere with livestock nutrition. This study was designed to assess the effects of a moderate increase in dietary sulphur in cattle. Twelve animals were initially fed a basal concentrate (0.2% sulphur) and then divided into two groups; one fed basal and the other high sulphur (0.75%) concentrates. Health, body weight gains, and activities of erythrocyte enzymes glutathione peroxidase, superoxide dismutase, glucose-6-phosphate dehydrogenase, acetylcholinesterase, aspartate aminotransferase, and whole blood concentrations of selenium were monitored at various stages of the study. The results indicated that a moderate increase in dietary sulphur would not impair selenium and copper status, nor cause related disorders in cattle (Khan et al, 1986).

Review of Field Data

There are a number of published reports on the effects of emissions, or sulphur compounds, on livestock. It must be stressed that these reports represent the sum of the individual effects of all the airborne pollutants to which the animals were exposed. These pollutants include both sulphur- and non-sulphur-containing compounds. It is difficult, if not impossible, to replicate such complex mixtures under the more controlled laboratory or field conditions.

CONCLUSIONS

Toxicological effects from sour gas, or acid forming emissions, may occur in livestock as a result of the simultaneous exposure to complex chemical mixtures containing sulphur compounds, and a variety of non-sulphur compounds such as ozone, ammonia, and the nitrogen oxides and other chemicals.

There is little anecdotal or scientific information available on the actual or potential effects on livestock of sulphur compounds associated with the recovery and processing of sour gas. In the exposure incidents that have occurred, accurate chemical data on the identification and concentration of sulphur and other compounds is not available. Under field exposure conditions, it is difficult to distinguish between effects induced by the exposure to airborne pollutants, and those which have occurred as part of the spectrum of normal biological variation. During periods of higher ambient concentrations, such as might occur during an industrial plant malfunction or sulphur block meltdown, a broader spectrum of pollutants may be present on a constant or fluctuating basis for a varying period of time. This transient and irregular characteristic makes it difficult to obtain dose response data from these episodes.

Catastrophic events, such as sour gas well blowouts, may provide sufficient information to distinguish between induced effects and normal biological variation. Unfortunately, information on the concentrations to which affected livestock are exposed is rarely available in sufficient detail to permit the determination of dose-response values.

Effects on livestock of naturally-occurring exposure to acid forming emissions are listed in Tables 6, 7, and 9. There is some agreement among the clinical observations listed in these tables, encountered during catastrophic situations like a blowout, with those observations made during experimental exposure of farm animals to hydrogen sulphide (Table 2). These are summarized in Table 10. It must be emphasized that exposure to hydrogen sulphide by itself is not the same as exposure to a blowout or sour gas plant emission. The long lasting effects on livestock exposed to hydrogen sulphide or to acid forming emissions have not been substantiated unequivocally. These effects include abortion, birth size, stillbirth, calf viability, late calves, weight loss, behaviour, and poor growth in replacement heifers.

The cost of investigating such effects, whether by detailed investigation during and after a gas well blowout or by well designed scientific experiments with livestock, is high in terms of money, resources and expertise. These investigations would require the cooperation of several provincial government departments and agencies, livestock producers, and veterinary practitioners. The effects from airborne pollutants will have to occur either in larger numbers, or with sufficient severity, to allow their unequivocal identification and separation from the normal and expected biological values and events.

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GLOSSARY

Term	Meaning
mg mL^{-1}	mg per millilitre
ppm	parts per million
mg m^{-3}	mg per cubic metre
g kg^{-1}	grams per kilogram
mL L^{-1}	millilitres per litre

Gas	ppm	mg m^{-3}
Carbon disulphide	10	30
Carbon monoxide	10	12.5
Ethyl mercaptan	5	10
Hydrogen sulphide	10	14
Methyl mercaptan	5	10
Nitric oxide	10	12.3
Nitrogen dioxide	10	18.8
Nitrous oxide	10	18
Ozone	10	21.4
Sulphur dioxide	10	28.56

Table 1. Approximate chemical composition of sour gas emitted from the Drummond 6-30 well.

Substance	Concentration
C_1	80.25%
C_2	3.99%
Condensate	124.0 mL m^{-3}
Hydrogen sulphide	11,400 - 15 000 ppm
Methyl mercaptan	57 ppm
Carbonyl sulphide	22 ppm
Ethyl mercaptan	14.7 ppm
Propyl mercaptan	14.3 ppm
Carbon disulphide	4.8 ppm
Butyl mercaptan	3.3 ppm

(Alberta Environmental Centre. 1986)

Table 2. Effects of exposure of livestock to hydrogen sulphide under experimental conditions.

Species Species	Concentration (ppm)[a]	Exposure Time[b]	Effects	Reference
GOATS: 3 - 4 yr, non-lactating females.	10	4 d	Little evidence of discomfort or alteration in physiological parameters.	Hayes, 1972; Hayes et al, 1972.
	50	4 d	Stress, feed & water intake to half normal levels, lacrimation, shivering, reduced urinary output.	
	100	4 d	Slight reduction in respiratory rate, transient conjunctivitis, shivering, reduced urinary output.	
CATTLE: mature dairy cows	20	21 d	Slight lacrimation, no change in milk production.	Hayes, 1972; Hayes et al, 1972
	20 - 50	21 d	Discomfort & alteration in normal body functions.	
CALVES:	20	7 d	Distress, lethargy, restlessness, occasional diarrhea and vomiting, coughing, irregular respirations and dyspnea, photophobia, keratitis, corneal opacity, nasal irritation, epistaxis.	Nordstrum, 1975 Nordstrum and McQuitty 1976.
	150	7 d	Severe keratoconjunctivitis, clinical blindness, reduced feed and water intake, elevated rectal temperature, lethargy, occasional diarrhea and vomiting, coughing, irregular respiration and dyspnea.	
PIGS: 13 - 21 kg	12	17-19 d	Little effect.	Curtis et al, 1974, 1975.

[a] parts per million; [b] d = day

Table 3. Summary of lethality of constituent chemical compounds found in sour gas, exposure is by inhalation route (Registry of Toxic Effects of Chemical Substances, 1985; Tansy et al, 1981).

Compound	Species	Lethality
Hydrogen sulphide	Rat	LC_{50} - 444 ppm/4 h
Carbon disulphide	Rat	TCLo - 200 mg m-3/24 h
	Man	LCLo - 4000 ppm/30 m (est)
Carbonyl sulphide	Rat	LCLo - 1400ppm/75 m
Methanethiol	Rat	LC_{50} - 675 ppm
Ethanethiol	Rat	LC_{50} - 4420 ppm/4 h

LC_{50} - (Lethal Concentration Fifty). That concentration of a substance in air, exposure to which for a specified period of time, that is expected to cause the death of 50% of an entire defined experimental animal population.

TCLo - (Toxic Concentration Low). The lowest concentration of a substance in air to which humans or animals have been exposed for any given period of time that has produced any toxic effect in humans or produced a carcinogenic, neoplastigenic or teratogenic effect in animals or humans.

LCLo - (Lethal Concentration Low). The lowest concentration of a substance in air, other than LC_{50}, which has been reported to have caused death in humans or animals. The reported concentrations may be entered for periods of exposure which are less than 24 hours (acute) or greater than 24 hours (subacute and chronic).

ppm = parts per million; h = hour; mg m^{-3} = mg per cubic metre; m = month.

Table 4. Threshold Limit Values (TLV) and Short Term Exposure Limits (STEL) for some airborne pollutants (NIOSH/OSHA, 1978; Amer. Conf. Gov. Ind. Hyg., 1986)

	TWA-TLV		TWA-STEL	
Compound	ppm	mg m^{-3}	ppm	mg m^{-3}
Hydrogen sulphide	10	14	15	21
Carbon disulphide	10	30	-	-
Ethyl mercaptan	0.5		1	
Methyl mercaptan	0.5		1	

TWA-TLV = Time Weighted Average - Threshold Limit Value: the time-weighted average concentration for a normal 8-hour working day, 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

TWA-STEL = Time Weighted Average - Short Term Exposure Limit: the concentration to which workers can be exposed continuously for a short period of time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, or (3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency, and provided that the daily TWA-TLV is not exceeded. An STEL is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day, even if the 8-hour time-weighted average is within the TLV. Exposures should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL.

Table 5. Effects of exposure to combinations of airborne pollutants on animals.

Pollutant	Concentration	Species	Observations	References
Hydrogen sulphide, ethylene, propylene, butylene, butane.	0.8 mg mL^{-1}	Rabbits, mice, man	Conclusion that higher toxicity exists from a mixture of hydrocarbons with H_2S than from any of the components of the mixture.	Filippova, 1963
Hydrogen sulphide, ammonia, carbon dioxide, methane	<1000 ppm <5000 ppm <300000 ppm <500000 ppm	Poultry, swine, cattle.	Manure from confinements, units, breakdown of ventilation. (Review)	Taiganides and White, 1969.

Table 6. Incidence of several conditions before, during and after the Lodgepole blowout episode.

	Number of farms affected		
Condition	Before	During	After
Eye irritation	11	23	20
Diarrhea	10	21	18
Dizziness/fainting	1	2	1
Heart irregularity	0	0	1
Unmanageable	5	12	5
Urinary	0	2	0
Skin	3	4	7
Pneumonia	8	11	8
Shortness of breath	4	14	4
Coughing	10	32	15
Abortion	21	31	33
Birth size	8	5	10
Abnormal at birth	7	6	14
Weight loss/gain	16	23	23

Pembina Area Sour Gas Exposure Committee, 1983.

Table 7. Summary of producer concerns following the Lodgepole blowout (Harris, 1986).

	Year					
Concern	80	81	82	83	84	85
Low birth weight	0	0	0	3	0	1
Stillborn or defective	0	1	2	7	2	2
Scours & Problem calves	0	1	1	3	1	0
Poor growth	0	0	1	6	1	0
Open or dry cows	0	0	0	3	2	0
Abortions	0	0	4	0	0	0
Late calves	0	0	0	3	6	4
Poor growth in replacement heifers	0	0	0	0	2	4
Abnormal hair	0	0	0	4	0	0
Abnormal breeding	0	0	0	0	2	1

Table 8. Costs of conducting investigations on the effects of acid-forming emissions on livestock health and productivity.

Parameter	Number of compounds under study 7 (separate)	 7 (combination)
Number of test groups:	37	78,733
Number of animals:	370	787,330
Estimated Costs ($):		
Purchase costs:	92,500	196,832,500
Maintenance/research:	810,300	1,724,250,000
Contingencies:	144,448	27,902,900
Total estimated costs:	1,047,248	1,948,985,400

Number of cattle per group: 10
Purchase price, per calf: $250.00
Maintenance and research costs, per day: $25.00 per group.
Contingencies: 16 per cent overhead.
Effects studied at each of four concentrations, namely zero (control), low, medium and high.

Table 9. Effects of exposure to gas well blowouts on animals.

Occurrence	Observations	Reference
New Norway	Watery eyes and noses in cattle cattle, diarrhea in swine.	New Norway Scientific Committee, 1974.
Lodgepole	Eye irritation, diarrhoea, dec. feed intake, excitement, nervousness, assisted parturition, weak calves, dec. milk yield, respiratory problems, coughing, reproductive disturbances, spontaneous abortions, unsatisfactory chemotherapy, weight loss.	Pembina Area Sour Gas Committee, 1983.
Lodgepole	Transient changes in activities of superoxide dismutase, glutathione peroxidase, glucose-6-phosphate-dehydrogenase, acetylcholinesterase, and aspartate aminotransferase.	Lodgepole Blowout Inquiry, 1984
General	Irritation of eyes and respiratory tract, cornea, respiratory problems, decreased production.	Beck, 1986

Observations made by veterinarians, farmers, and/or research scientists.

Table 10. Comparison of effects observed with farm animals during exposure to emissions from sour gas under uncontrolled (natural occurrence) and controlled (experimental) conditions.

Condition	Uncontrolled	Controlled
Production	X	
Reproduction	X	
Poor doers	X	
Respiratory-ocular	X	X
Gastrointestinal	X	X
Metabolic	X	

RESEARCH METHODS WHICH CAN BE USED TO DETERMINE THE EFFECTS OF ACID FORMING EMISSIONS IN LIVESTOCK

R. Church

I would like to summarize some of the things that we have been involved in during the last twenty-odd years, and then look at some of the new things that are coming down the pike. I will try to put into context some of the technologies that we have used for some time. In particular, I want to refer to those sources in Alberta that are the real experts in certain areas of analytical technology.

The first study of acid forming emissions was originally commissioned by McKinnon, Allen, et al., and Jim Lore. The basic design of that particular program involved the Pincher Creek area, an area that was downwind a considerable amount. The transposition of animals and materials was going both ways, so the controls were there. But, as with many such projects, just about the time the researchers found out how to really do the job and the results began to get interesting, the funding quit.

The program that I want to talk about right now is a program for which I must give full credit to Bill Bowser, then Head of Soil Survey at the University of Alberta. At the time of the program, I was involved in our family ranching operation, just northeast of Calgary. My home town is Balzac. What was then Jefferson Lake originally bought Section 1 to establish one of the first sour gas processing plants right on the creek, on the rail line, next to the Number Two Highway just north of Calgary. The Department of Transportation was concerned because of the proximity of the International Airport. They said they did not particularly want their airplanes observing the flue pattern of the stacks quite that closely. So a switch was made whereby the land was traded.

A study was set up with experimental and control areas. All of the cattle in this particular study were wintered as a purebred Hereford operation on the west side in one particular area. The cultivated land they had been wintered on is adjacent to a control area and it is upwind three miles from the plant itself. All of the calves were kept in a common feedlot. Replacement heifers and purebred bulls were also wintered together, and were all on an ROP program of our own design. The cows were calved out adjacent to the control area, once again on the west side of Number Two highway. Just about spring, in the middle of June, the cattle were taken out.

With the help of Bill, we established a grid system on one half section. A small area of alfalfa brome hay was not included in the analysis. The interesting thing was that this half section and the controlled quarter section have never been cultivated. It has always been used for either native hay or summer pasture.

I should indicate that, in 1961, when what was now the Petrogas Plant came on stream, there was a well that was drilled just south of the Plant. It was the first of the rigs to move into that particular area; tapping, of course, the Elkton and Crossfield area, with the Crossfield being 32% sour. The initial installation sulphur was put into the solid block piles as shown here. These were the first piles formed, and during the initial years - until the slaters were installed in 1973 - there was considerable movement of elemental sulphur downwind. As a matter of fact, it was not unusual, after a recent snow and a chinook, to have what we used to call "The Yellow Snow" for a full mile over the study area. The next phase was the solid blocks and those had a little more organization since the industry had increased its ability to handle these piles. Some of the things that we tried to do in the initial experiment included an analysis of the soil from a growth point of view, an analysis of vegetation for floral analysis, and an attempt to follow the performance of the cow herds that summered in this particular area. The cow herds, I want to mention again, were all wintered in one particular area, calved in one particular area, and fed on feed that came from an upwind source some miles north. The common denominator was that it was a purebred herd. Groups of 25 to 35 cows were put with a single sire breeding unit. The pattern of a cow's reproductive history, therefore, might involve her being located 3 or 4 years in the study area, maybe a couple of years in the control area, or somewhere else. The assignment of the cows to any particular pasture was not a function of the study, it was a part of the herd management.

We initially thought that we could easily determine things like soil pH. It is hard to determine, however, in a light soil zone such as this, which has a high lime content layer. We assessed a free water pH and an absorbed water pH, and then tried to establish the hydrogen ion concentration. We have an assessment of the absorbed water, and this is what is reflected in these particular values. You will notice in the control area and in the study area that there is high pH, common throughout the initial stages. This is characteristic of this part of the world.

The second point that I would like to make is that we did not notice a drop in pH for a considerable number of years. This was adjacent to places where elemental sulphur was blowing off the pile. After 1978, an increasing number of sites showed a drop in pH. It is very difficult to have a great deal of confidence in exactly what soil pH means here.

We looked at microelements using the classical analytical techniques and combustion techniques, and we were concerned with variability and heterogeneity. In the last microanalysis, we used the arc spectrophotometer. This is better than conventional combustion techniques. The heterogeneity between duplicate samples decreases substantially. The arc spectrophotometer was originally used in Colorado, and more recently at the University of Saskatchewan.

We also looked at vegetation. With the help of Bob Ogilvie, we simply did a floral analysis and monitored the change. We checked one-yard-square duplicate sites as indicated in the study program but we did not do a clip and weight, or an individual grass analysis, as you would if it had been a more controlled experiment. There are a number of anecdotal aspects associated with the apparent palatability of the vegetation. We found that on a horseback ride in the fall, not only would our horses be coughing, but our eyes would be running too. As the program progressed, there was a decreased palatability of vegetation except after a recent rain. Animals moved back from the plant in dry periods in particular.

As far as I am concerned, the conventional analyses are absolutely useless for assessing the vegetative productivity and the biological values. There are some new technologies which Allan Legge and Roy Krause have exploited nicely in the Whitecourt area, using the stable isotope mass spectrometer approach. This involves ascertaining the difference between the isotopes associated with the surface and the differential sulphur isotopes associated with the wellsite. This is eloquently documented in Legge et al. and is based on Roy Krause's stable isotope mass spectrometry expertise. In this particular case people should be using the infrared spectrophotometer.

A new facility has been established at the University of Saskatchewan, and there will be one here in Edmonton in the near future, which will attempt to assess the basic biological nutritive value of the forage. This is opposed to the gross analysis which we have used before. To give you an example of how gross this was, protein is still expressed nitrogen x6.25. When we look at actual animal productivity, we see how inadequate this level of analysis is. There are also problems with animal models and approaches to animal environmental interactions in conjunction with an acid forming emission study. The studies tend to be after the fact and they tend to be short. Also, most of the animals do not have genetic or pedigree documentation as to their reproductive growth or milk performance. Money is a good part of the reason for this.

In our particular instance, we were fortunate in that we had a purebred herd and we basically knew the cow's previous history. When establishing this kind of a program, it is not really of much value to go to the auction mart and buy a number of cattle to put on trial. You don't know the background of these cattle and you don't know what their reactivity is going to be. General production makes these studies difficult. For instance, the chicken is a very high production unit. If it is under considerable stress, any impact will probably show up fairly soon. On the other hand, the beef cow will probably need some time for any impact to show up. The third aspect making these studies difficult is the lack of reproductive records. I suspect that there are only two or three herds in Alberta where you could ascertain with any degree of accuracy the reproductive history of a particular animal in that herd on the basis of the records. A further complication of the accuracy of these studies is that dead animals usually get to the veterinary laboratory when they are bloody sick, and then the veterinary pathologist is expected to differentiate between the effects or alleged effects of an incident, the mismanagement of the operator, and/or the stress that may be associated with secondary pathological conditions or disease in that particular animal. The pathologist is put in a position where it is almost impossible for him to carry out an accurate postmortem.

A lack of complete nutritional records also contributes to the problem. Traditional feed analysis has been almost useless in establishing the nutritional status of a herd. Fortunately, with the new infrared spectrophotomatic analysis, the biological assessment may come much closer to assessing the real feed value, at least in relation to ruminants.

A lot of faith has been put into blood and biopsy analyses. But in most cases, because of our lack of knowledge of the molecular biology, the pathology, and the molecular physiology of most domestic animal species, we really are shooting in the dark. We might have thought a particular enzyme was involved because it seemed to be a critical enzyme in a metabolic pathway; or we believed it was involved with an important parameter in physiology. In fact, it didn't matter whether we analyzed a sample with a mass spec GC, AA, or any other type of bioassay, the blood and biopsy analysis could never be easily defined. Hair analysis is another area we have been studying. We have been trying to develop the stable isotope mass spectrometer approach, based on Roy Krause's technology. Allen Legge successfully used this in the vegetative program at Whitecourt. Every time we think we have gotten to the point where it's a repeatable analysis, we have ended up with results which didn't fit anything we had ever seen before.

To look at effects as subtle as most of the hydrocarbon industry-animal production interactions, we have had to look at "statistically significant numbers". And we are going to miss some animals that could tell us something. Let me give you an analogy. When I was an undergraduate student, animal models provided most of the data we used in human medicine. Recently that has changed dramatically. As a result of the thirteen billion dollars that was assessed to cancer research in the United States in the late 60's and 70's, we know more about the molecular biology, the molecular genetics and the molecular physiology of man than any other species. Now we are in the situation of having to apply some of that knowledge to our animal analyses. You tend to look at the average and forget about the tails. And it's the tails that tell us things.

The variability and the microheterogeneity within the DNA sequences of the human which we can measure with enzymes is such that every one of us in this room can be identified on the basis of the enzyme analysis. That tells you a little bit about how much heterogeneity there is within the genetic information in this room. It also means that as a result of the information that we now have, using genetic engineering techniques as applied to our immune systems rearrangement and microevolution are occurring in the immunological system of each one of us. This is our accumulative history from the time when we were a fetus to now. In addition, we know that in terms of the hypothalamic pituitary processing of genetic information there is a tremendous amount of subtle detail controlled, coordinated and processed all the way from the genome through to the endpeptide. For example, one single peptide is synthesized as a long peptide in 11 different neural cell types. However, in those 11 types, each cell specifically takes a fragment of that long peptide and makes a hormone. And, that hormone is as different as MSH and endorphin, which have major physiological effects on your body.

Let's look at some of the model systems available to us. First, we can't buy a group of animals in the auction mart and then assume we have a random population. Secondly, we still have to extrapolate back to the individual animal in a given management system. Looking at some of the model systems that are either already in existence or available in experimental models, we see the first one is the inhalation chamber. The unit at Vegreville is probably one of the world's best inhalation facilities. Of course, it is primarily designed for rodents. Sheldon Roth and his colleagues have developed an inhalation chamber which utilizes small groups of rats. It is designed, through various controls, to be able to expose a limited number of animals to specific concentrations of various mixtures of gaseous toxicants. We tried some years ago to develop a technique for ruminants but all we succeeded in doing was frustrating our technicians who had to play cowboy because the animals objected violently to the inhalation chambers and the inhalation apparatus. It doesn't mean that it can't be done. It's simply that large animals are prohibitively expensive. That's why we need to know more about the actual animal and its history.

The second area of study involves using neuronal cell preparations. This can be done with marker species, invertebrate species, or it can be done with brain slices from higher animals. Sheldon Roth and Nick Nation are also involved in this in Alberta. These studies entail assessing the neural cell physiology at a cellular level. This means that very, very low physiological concentrations, not pharmacological concentrations or even the gross concentrations we tend to use in some of our experiments, can be put into a system. However, there is absolutely no value in putting compound X into a system and getting an observed change in contrast to a control unless the experimental design includes a wide array of the compounds that are normal constituents of the animal's environment under "normal conditions". So the controls have to be very carefully selected.

A third area of study is microcell or micronuclei or mitochondrial DNA fragment analysis. This area of study attempts to assess the heterogeneity or the mutagenecity that results in the peripheral circulation of an animal on exposure to various mutagens in our environment. This is in addition to the usual mutagens that are commonly there, for example, the cosmic radiation from our environment. These types of analyses are now being done in human populations to assess occupational health hazards. The studies have been conducted by groups such as David Hors and Noreen Ruds, and a large group at the National Institute of Health in Bethesda, Maryland. There is also a large installation now being established in the Department of Clinical Ecology at the University of Texas.

If we were to assess everyone in this room, and expose them to common immune stimulants, we would end up with 40 different profiles. That's an example of what I mean by having to assess the individual's basic "evolutionary history" in conjunction with the genomic sequence each individual is carrying around. Then when we have established the molecular biology and physiology for the individual we can start looking at that individual, not at large numbers. We have spent a lot of money getting maybes or negative results. The bottom line is that each animal is unique - each animal reacts differently - and the results will show tremendous variation.

As our technology couples with the basic genetic and physiological information of the individual, we will get innumerable permutations and computations. We need to know more about the molecular biology and physiology of domestic species to exploit this. I think that instead of using multiple groups of animals and looking at averages, we must be able to characterize or design backgrounds for the animals we are going to expose under control conditions. It is now possible to use groups of animals that have been produced by nuclear transfer. These animals will be "identical twins or clones" so we can eliminate one of the variables. This means that we will have the ability to manipulate the evolutionary physiology of the immune system of particular groups of animals, or of individual animals, from the fetal period until the end of the life of the animal. And we will be able to look at specific interactions at different exposures, under different environmental conditions.

My guess is that we are going to have answers within the area of human occupational health, coupled with molecular biology and genetic engineering diagnoses, long before we have the same kind of data for our domestic animal species. I think that we are going to have to read very different literature to keep up-to-date on the interactions that occur. However, the farther up the food chain we go, the more difficult it becomes to establish the differences. We are also going to have to have some sort of system in place so that we know the background of the animals involved when accidents occur. I think some of the things that we are greatly concerned about at the present time will fall by the wayside, and some things that we are very complacent about now will have a major impact.

Probably the two most successful programs for cancer therapy and diagnosis at the present time are not running within grant systems. They are not running within the regular medical care systems. They are running as independent institutes. They are utilizing biotherapeutics. This involves extracting tumour cells and then making monoclone antibodies, or DNA probes, specifically for your tumour cells. These are then hooked onto a specific agent which stops cell division. You are treated with monoclonal antibodies specific for your tumour and carrying a specific chemotherapy agent. My guess is that this will be the most effective of the many approaches that are being used. So I will say, then, that the individual is the thing that we should be concentrating on. Thank you for listening.

Questions/Answers

1. Question. Bob - One of the areas of concern in the sour crude and gas situation relates to reproduction. We have talked about how we might determine whether or not there are some hormonal-like compounds in these substances. I wonder if you had some concept as to how this might be approached in research.

2. Answer. That's a deceivingly simple question - to which I don't have an answer. For a number of years, we have tried to get a handle on the reproductive aspects. As I said, you can't make head nor tail from our inhalation experiments. We did do a series of experiments with groups of cows that we bought from purebred herds to try to get an idea of their reproductive history and nutritional status. We delivered sweet and sour

crude directly to the rumen of these particular animals. And then we measured LH and FSH and the steroids. We didn't see a damn thing. At that time we didn't have the necessary diagnostic technology to monitor releasing factors. We now have that and we are just about to repeat that particular study.

We had some cattle that were going to the slaughter house and we put out some pails filled with oil from different sources and let the cows drink it. Axle grease and crankcase oil were used as a potential treatment for lice, mange and things like that years ago. So it was interesting that some animals could drink a gallon without any problem whatsoever, and most would drink a quart without any problem. But if you took ten of those animals, you would find that some of them would lose a tremendous amount of weight, some of them would go into an estrus and some of them would have no reproductive problem at all, some of them would abort in the first trimester and some of them would not do anything. The hormonal data that we have bore no correlation whatsoever to what the animal did, except for LH. We are now going to try the study again using the releasing factor assay, and LH and FSH. We are also planning to use a GC mass spectrometer that looks at steroids, and steroid derivatives and analogues, at a more detailed level than what was possible before. We were using embryo transfer to try and get our numbers up a little bit. In the not too distant future, we want to look at some of Sheldon Roth's inhalation neurobrain slices, and then put our reproductive neuropeptide bioassay or ELISA systems together with that.

COMPATIBILITY OF AGRICULTURE AND PETROLEUM INDUSTRY

W.C. Edwards

My presentation will be on some problems that I have observed in the agricultural-petroleum industry interface. As for myself, I have been involved in drilling oil wells for 20 years and I have practiced veterinary toxicology for essentially the same period of time. Tonight, as your after-dinner speaker, I will present some of my observations on the agricultural-petroleum industry interface.

With some 108,000 producing wells in Oklahoma, you can see that our state looks something like a pincushion (picture). Since well sites and road right-of-ways take from 3 to 5 acres, the oil and gas industry is a significant consumer of agricultural land.

Things get started in the oil field when the land man negotiates a lease with the mineral owner or lease holder. Surface damages are settled with the land owner and the rotary rig starts drilling operations on the well site. The interface between drilling operations and livestock can result in livestock damages.

A wide variety of chemicals are used at the drill site. Bentonite clay (picture) is generally the principal constituent in drilling fluid. Other chemicals present are: (pictures) caustic soda, chromates, asbestos, and crude oil and other petroleum substances. Inert materials used include pecan shells and chicken feathers. If circulation is lost, almost anything will be used to restore circulation.

Used paper bags of caustic soda (picture) get blown about by the high winds in Oklahoma. Cattle will chew or attempt to eat these bags and a cup or two of caustic soda can be ingested. Caustic soda causes damage to the esophagus and rumen, and animals with caustic burns of these organs generally die.

Another chemical used at the drill site is thread collar compound (picture). This material can be 30 to 50% lead. Thread collar compound is a soluble form of lead and is absorbed from the gut as well as through the skin. It takes about two teaspoons of this material to produce lead poisoning in a mature cow. This glove (picture) was taken from the rumen of a cow. There was enough lead in this discarded glove to kill an adult cow.

Cattle have been poisoned by licking discarded pails that were thrown in a reserve pit (picture), only to resurface later. Note that this reserve pit (picture) contains empty beer bottles, a little crude oil, and chemical containers. This is a common sight (picture) in Oklahoma. Fencing these pits would alleviate a number of our problems.

Cattle, especially calves, can fall into mud pits (picture) and suffer exhaustion and drown. However, most of the rig operators are careful and try to prevent this kind of incident from occurring.

After the well is drilled, the logging operations begin. Occasionally, a radioactive tool may be lost down the bore hole. Then the Nuclear Regulatory Commission comes in, and may seal the bore hole. These incidents rarely result in toxicological problems.

Following logging of the well, the well may be fracked. The modern fracking operation forces acids, gases, sand, or other substances down the bore hole under high pressure to chemically alter or fracture the formations, allowing oil or gas to flow into the well. Fracking operations use hydrofluoric, formic, acetic, nitric and sulfuric acids, as well as some other chemicals, in large quantities. If a well blows during the fracking operations, the substances used in the fracking operation, plus the well constituents, end up on pastures and crop lands.

A problem that can occur during all of the oil field operations is spillage of automotive fluids and fuels. Of these, diesel fuel and ethylene glycol are the most common poisonous substances. I have a picture of a site where the farmer lost several head of cattle from diesel fuel ingestion.

If the oil well produces, a pumper is set and a separator and tank battery are installed. At our laboratory, we have found that animal poisonings associated with producing oil wells occur more often in the winter months. This is because cattle use the pumper and tank battery as shelter from the cold wind. We have found problems such as salt water poisoning, lead poisoning from oil and grease, and injuries caused by the moving parts of the pumper unit.

Ingestion of salt water is a common problem. In Oklahoma, 6 to 8 barrels of salt water are produced for each barrel of crude oil. This means that oil producers must dispose of lots of salt water. Salt water ingestion can occur when the cattle open a valve on a salt water tank, when there is leakage from broken salt water pipes, or when there is contamination of dugouts with salt water. Another source of salt water ingestion may occur when salt water is held in brine pits before proper disposal. When the fresh water ponds freeze up, cattle will drink from a brine water pit. Concentrations >1% are hazardous to cattle and cause salt poisoning.

Salt water can be disposed of by injection into disposal wells. The high pressure lines (picture) used to do this can criss-cross pasture lands. And, due to corrosion, there may be breakout problems. Thus, soil that has been contaminated with salt water does not support vegetation and becomes eroded (picture). Salt water from leaking pipes can also contaminate fresh water dugouts used by livestock. And there can be a number of dead cattle in a very short period of time. On the farm in this picture, the pipe had a kink in it and the pond water (picture) contained 3% salt.

Cattle licking the polish rod of a pumper are a common occurrence. Packing compound can contain lead, and cattle are poisoned from ingesting this material. Lead based greases are also used to lubricate some of this equipment and lead poisoning occurs when cattle lick the grease. If the packing box leaks, intoxication with crude oil can occur.

Arsenic is used as a corrosion inhibitor and herbicide. These cattle (picture) died of arsenic poisoning after the operator sprayed the ground around the well to control weed growth and reduce the fire hazard. In this case, salt was not available for the cattle and they licked the soil which contained sodium arsenite.

Chromates are also used as rust inhibitors. Clinically, chromate poisoning looks much like arsenic poisoning, and we encounter 4 to 5 incidents of chromate poisoning in cattle each year. Ammonium chromate (picture) is a yellow powder with a salty taste. Some of the chromates may be orange or brown (picture). In one case of chromate poisoning, the suspect material was 43% chromium. The kidney from the dead cow contained 15 mg of chromium/kg of tissue and the abomasal contents contained 500 ppm. In a different case of chromate poisoning, the suspect substance contained 10,000 mg of chromium/kg of substance. The blood of the animal that ingested this substance contained 1.08 mg of chromium/L of blood.

Broken transmission pipelines and leakage of petroleum substances allows cattle access to these substances. Here is a picture of a crude oil pipeline that was broken during a flood. Debris carried by the flood water jammed against the pipeline, causing the break, and spilling several thousand gallons of oil into the creek. We discovered that a number of purebred Angus being water from the creek were passing oil in their manure (picture).

As an oil man and a veterinary toxicologist, I see both sides of the interface between the oil and gas industry and agriculture. It has been a pleasure to be your after-dinner speaker.

FINANCIAL SUPPORT FOR AGRICULTURAL RESEARCH IN ALBERTA

Y. Teklemariam and J. Martin*

INTRODUCTION

I have been asked to talk about potential funds available from Alberta Agriculture for research on the effects of acid forming emissions on livestock. Alberta Agriculture's main research funding program is called "Farming for the Future". This paper presents a brief summary of the objectives and operational guidelines of "Farming for the Future".**

Program Description

"Farming for the Future", supported by the Alberta Heritage Savings Trust Fund, was announced in late 1977, and the Agricultural Research Council of Alberta was formed in early 1978 to administer the program. Although some projects were funded in 1978, full operation commenced on April 1, 1979. The program's first mandate ran for five years to March 31, 1984, and during that period, a total of $25 million was allocated to Farming for the Future from the Heritage Fund for research and demonstration projects. In 1983, the program's mandate was renewed for a three-year term (1984-1987) with an annual allocation of $5 million. A five-year extension, to March 31, 1992, has recently been announced by the Minister of Agriculture, the Honorable Peter Elzinga.

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* Person who presented the paper.

** The reader or the potential applicant should refer to the official Farming for the Future Terms of Reference and application form for a detailed description of program requirements.

Objectives

Farming for the Future has two main objectives:

1. To improve net farm income.
2. To increase the long-term viability of agriculture in Alberta.

These objectives are met through two funding vehicles: the Research Program and the On-Farm Demonstration Program. The Research Program funds agricultural research conducted by research scientists and the On-Farm Demonstration Program supports testing and demonstration studies conducted by producers on their farms. The testing is done in cooperation with district agriculturists and specialists or scientists depending on the nature and complexity of the proposal.

These two programs compliment one another. The results of research studies are effectively communicated to producers through demonstrations. Likewise, interactions with farmers and extension personnel provide scientists with information about research needs.

During 1986/87, the Research Program awarded a total of $4.56 million to 36 new projects and 58 renewed projects for a total of 94 projects. The On-Farm Demonstration Program, allocated $600,0000 for

1986/87, has granted over $340,000 to 78 new and 23 renewed demonstration projects.

Application for Funds

Since most of you will be interested in the Research Program rather than the On-Farm Demonstration Program. I will focus on how to apply for research funds.

"Farming for the Future" is administered by the Agricultural Research Council of Alberta. The council is composed of:

- The Minister of Agriculture, as Chairman
- The Deputy Minister of Agriculture, as Vice-Chairman
- Eight active Alberta producers
- Representatives of:
  - University of Alberta
  - Alberta Research Council
  - Alberta Agriculture
  - Legislative Assembly
  - Agriculture Canada
  - Alberta Irrigation Council
- The Director, Alberta Agriculture Research Division, as Secretary.

A broad range of interests are covered by the scientists, producers and legislators on Council. Their joint expertise ensures that the proposals supported meet the research needs of Alberta's agricultural industry.

Reporting to Council are nine program committees:

- Cereals and Oilseeds
- Crop Protection and Entomology
- Forages
- Irrigation
- Land Resources and Engineering
- Non-Ruminants
- Processing, Transportation, Marketing and Socio-Economics
- Ruminants
- Special Crops.

These committees review research applications and provide recommendations on funding to the Council, and are chaired by members of the Council. The committees are composed of representatives from Alberta Agriculture, other government agencies, and universities, as well as producer representatives.

To apply for funding you must complete a detailed application form that outlines the proposed project. Each applicant must outline the objectives of the project, statistical analysis to be applied, cost estimate, and qualifications, as well as the track record of the researcher(s) and the organizational capability to undertake the work. It is very important that the application form contain complete and accurate information about the proposed project. Since the approval or rejection of the proposal is based on the information presented on the form.

The deadline for submission of applications for funding under the Research Program is November 1st of each year. Applications are then processed by Alberta Agriculture's Research Division and by mid-November, are sent to the appropriate program committee. The program committees meet in December and January to review the applications, and to develop recommendations for the Council. The Council meets in February and reviews the applications in conjunction with the committee recommendations. Applicants are advised of Council's decision following Council's February meeting. Funding for the approved projects begins on April 1st.

Criteria for Evaluation

As researchers, you will be interested in the criteria by which proposals are evaluated. At "Farming for the Future", we look for projects with potential for a large contribution to science (expanding the frontiers of agricultural knowledge) and large economic benefits to the agricultural industry. Proposals with large contributions to science only, or those that apply existing knowledge to solve industry problems fall into a subsequent category. When the program committees and the Council evaluate proposals, they consider the following areas:

1. The significance of the proposal to the advancement of Alberta's agricultural industry, and to the improvement of the industry's competitive advantage.
2. The soundness and completeness of the research design.
3. The "track record" of the project manager/principal cooperator, as indicated through experience and demonstrated capability in the area of the project proposal.
4. The competence and productivity of the researcher(s) over the preceding three years, as demonstrated by publication of scientific articles in refereed journals in the discipline entailed in the proposed research.
5. The size, duration and cost of the project.
6. The organizational capability and commitment of the applicant(s) to complete the project.

The researcher in charge of the project is judged on his/her academic qualifications with respect to the proposal's research area, and on his/her publications in refereed journals concerning the research area. Past performance is judged by how well research objectives were met, and how efficiently the project was brought to a timely conclusion.

The relevance of the proposal is evaluated with respect to the background and objectives described on the application form. The significance of the proposal to Alberta's agricultural industry is of prime importance, but its significance with respect to the development of science is also considered.

The research design is very important. The objectives of the proposed project must be clear and well defined. The proposal must show that, if funded, the project could achieve its objectives. It must also show that appropriate scientific methodology will be applied in data collection and analysis, and that the project can be completed in a timely manner. Finally, the project costs must be within reasonable limits, be directly related to the project, and be accurate.

Successful applicants receive their award at the beginning of the fiscal year. They are required to submit a progress report in November of the following year, if the project is to continue beyond one year. A final report and complete financial statement are due after the completion of the project, that is, within three months of the end of the last fiscal year in which funding was received for the project.

Funding for Acid Forming Emission Research

"Farming for the Future" has yet to support any projects relating directly to the effects of acid forming emissions on livestock. Such projects are not necessarily outside the program's objectives, but the burden is on the applicant to show that the expected results of his project would be important to the advancement of Alberta's agricultural industry.

I trust this paper has helped you to understand how "Farming for the Future" operates. The Research Division of Alberta Agriculture will be pleased to provide any further information you require or answer any inquiries you may have. We look forward to hearing from interested applicants. Our address is as follows:

Research Division, Alberta Agriculture
#306, J.G. O'Donoghue Bldg., 7000 - 113 Street
Edmonton, Alberta T6H 5T6 (Telephone: 427-1956)

Questions/Answers

1. **Question.** Dr. E.L. Snider. Two very important things came up in our conversations that were not in your presentation. In this day and age of research monies being in short supply, can you explain the appropriateness of government agencies such as Alberta Agriculture and Agriculture Canada applying for "Farming for the Future" research funds. I think the group would be interested. It is a big chunk of money that the federal government gets from this organization.

   Answer. Last year, new projects for Agriculture Canada were not funded simply because there was a dispute between the governments. Our government felt they were cutting back on their research expenditures in Alberta. It was assumed that what we were doing was covering the shortfall. It's a question now that is certainly being debated.

2. Question. Dr. E.L. Snider. Part of what I do is apply for research grants. I have the feeling that I have to find an unlisted number somewhere in a phone book, and the address is impossible. When I make an application, it seems there is a slot in a door somewhere in an alley. This group has been very much different. If you need assistance, there is someone there to answer your questions. And they appoint someone in the department or group to help you with your proposal. There is no guarantee of success, but certainly if there are people inside who are interested in what you are doing, you have people to talk to. It's straightforward and above board. I would urge you to consider making that point as part of your presentation in the future; because to non-aligned researchers, it is a very important piece of information.

Answer. Thank you very much, Earl. If people ask questions, and ask for help or advice on what they are putting together, we would be pleased to do whatever we can to help them along.

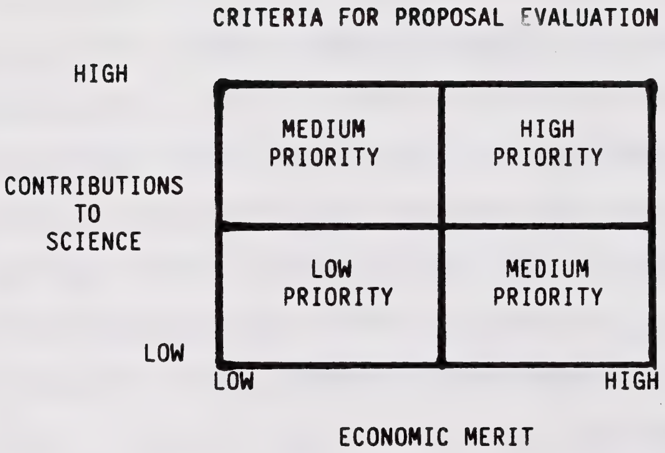

Figure 1. Diagram of criteria used for evaluating "Farming for the Future" Applications.

POTENTIAL RESEARCH MONEY AVAILABLE FROM THE ACID DEPOSITION PROGRAM AND ALBERTA ENVIRONMENT

Carl L. Primus

Introduction

It is exceedingly difficult to demonstrate definitive long-term changes in animal health as a result of acid-forming emissions. This issue is complex because, under ambient environmental conditions, it is difficult to distinguish between effects induced by the animals' exposure to low-level airborne pollutants and those effects occurring as part of normal biological variability. The problem is further compounded by the difficulty in identifying the causative agents (i.e., the specific pollutant), the direct and/or indirect interrelationships between pollutants and health, and the manifestation of the resultant effect. This resultant effect may be as simple as running eyes or more subtle, such as changes in fertility and productivity.

Because of the complexity of the problem, answers or solutions are not easily provided. There is little information on the actual or potential effects of air pollutants on animal health, particularly, the effects of sulphur compounds associated with the recovery and processing of sour gas. If effects occur, they may be the result of the cumulative exposure to one or more sulphur compounds and a variety of non-sulphur compounds, such as, ozone, ammonia, nitrogen oxides, and heavy metals. Unfortunately, information on the ambient concentration levels of pollutants is rarely available in sufficient detail to demonstrate cause-effect relationships. The effects induced by airborne pollutants must occur either in large enough numbers or with sufficient severity to allow their unequivocal identification and separation from the normal and expected biological responses in animals. The low incidence of impact over the short- or long-term makes it difficult to demonstrate cause-effect relationships.

The research required to address the complex question: "Do acid-forming emissions affect animal health?", is both time intensive (i.e., long term) and expensive. Nonetheless, the question is important to Alberta, since the greatest density of sour gas wells is in the west central area of the province. This coincides with the major economic livestock production area for beef, dairy, swine, and poultry.

Current Research

Preliminary research on the effects of acid-forming emissions on livestock is or has been done in Alberta. The investigation of the problem requires cooperation from various agencies. The Department of Agriculture and the Alberta Environmental Centre (AEC) investigated the impact of the Claresholm blowout; and Agriculture has recently published a follow-up report to the Lodgepole blowout inquiry. AEC has undertaken an inhalation toxicology study on the health effects of sulphur gases. The objective is to determine the effects of toxic or potentially toxic gases, vapours, particulates, and aerosols on animals and, by extrapolation, on humans. Studies include:

1. The characterization of a 69 L inhalation exposure chamber.
2. The commissioning of a new 359 m^2 inhalation toxicology containment facility.
3. Studies on the acute toxicity of hydrogen sulphide.
4. In vitro studies and techniques for evaluation of adverse effects of pneumotoxicants.
5. The implementation of an inhalation exposure system using 2 m^3 exposure chambers.
6. The field investigations of possible effects on livestock.

The inhalation toxicology program addresses the needs of several client departments including Agriculture, Community and Occupational Health, and Environment.

Potential Funding

The Alberta Government/Industry Acid Deposition Research Program (ADRP) has been approached regarding the funding of animal health research. The Members Committee does not foresee becoming involved in the long-term and complex research required to address the effects of acid-forming emissions on livestock. It must be kept in mind that the effect of acid-forming emissions on animal health is only one component of the overall issue of acid deposition. Our knowledge regarding the transport and deposition of acidic or acid-forming substances and the environmental effects on both human and animal health, is presently limited. Research and monitoring programs need to be implemented or expanded to overcome our knowledge deficiencies. However, funds are limited for the necessary research to address all facets of the acid deposition issue. And the research required will be complex and long term.

The research focus of ADRP has centered on the effects of emissions from the sour gas industry in southwestern Alberta on agricultural productivity and human health. ADRP is an $11 million undertaking by the province, industry (Canadian Petroleum Association, Alberta Power, Edmonton Power, TransAlta Utilities) and the Energy Resources Conservation Board. Eight million dollars of this amount has been allocated to biophysical research and is jointly funded by Alberta Environment and industry/ERCB. The $3.7 million for human health research was funded completely by Alberta Social Services and Community Health. The Members Committee of ADRP opted to allocate the available funds to biophysical and human health research to ensure the initiation of a scientifically credible research program, rather than applying the limited funds to these two areas plus animal health research, and possibly jeopardizing the credibility of the program.

To ensure the protection of our environment, Alberta Environment has developed research and monitoring programs which address major research priorities in waste management, water resources, air quality/climate, acid deposition, reclamation, and environmental contaminants. The research and monitoring aspects of each program are complex and long term, and will require substantial financial support. The programs are designed to assist the department in:

1. Investigating the impact on and response of our physical environment to pollutant exposure, industrial effluents, spills and natural releases.
2. Developing effective monitoring and control strategies.

The total research budget is apportioned among all of the programs. However, the budget is not sufficient to address all of the major research issues identified, so priorities are set for each fiscal year. With respect to acid deposition research, the departmental program is comprised of four distinct, but integrated components in addition to ADRP. These are:

1. Alberta Environment's acid deposition effects research program in the Athabasca oil sands.
2. Western and Northern Canada Long Range Transport of Air Pollutants.
3. Departmental Monitoring Program.
4. Inhalation Toxicology and Animal Health Program.

A considerable budget is currently being utilized to research and monitor the environmental and health effects of acid-forming emissions. Animal health research, although a component of the acid deposition issue, is beyond the mandate of Alberta Environment. However, this does not preclude other groups from funding and coordinating the research. Accordingly, any funds for additional animal health research must come from other government departments and agencies whose mandate covers this area.

I look forward to constructive input from researchers and producers attending this workshop in identifying what research is required and how best to develop and implement it.

Acknowledgments

The author wishes to thank the staff of Alberta Environment for their assistance in preparing this paper.

INSTRUCTIONS TO THE PLANNING GROUPS

M. Kostuch

The papers presented at this workshop have provided us with a considerable amount of information to be evaluated by the Planning Groups. Each of you are admonished to review the anecdotal and research information presented, ponder the problem, and subsequently, to identify the information gaps. You are also to focus your attention on the needs for future research, governmental policies and other appropriate actions.

Each of you has been assigned to a Planning Group and each Planning Group has been given a number. The tables are numbered 1 to 5 and the table numbers correspond with the Planning Group number. If you have not been assigned to a Planning Group, we will assign you to one. We also ask that you attend the Planning Group to which you have been assigned. Each Group has an appointed Group Facilitator; however, each Group will need a recorder/reporter.

The procedure will be as follows:

1. Identify information gaps by reviewing the papers presented and by evaluating any other information that may be available to your group.
2. Prioritize the information gaps.
3. Make a recommendation for each information gap.

4. In a 5 minute platform presentation, report your recommendations to the workshop.
5. After the group presentations, Dr. Lillie will summarize the presentations in concluding remarks.

Questions/Answers

1. **Question.** Dr. E.L. Snider. Could you explain how people were assigned to the Planning Groups? There may be ten individuals interested in one issue, and they are, in fact, spread through five Groups.

   Answer. The procedures to be followed in assigning individuals to Planning Groups were decided in a meeting of the Group Facilitators. Two alternatives were discussed: organize the Planning Groups by disciplines or interests, or structure heterogeneity into the Planning Groups by assigning individuals to a particular group. The Group Facilitators chose to have heterogenous Planning Groups because this optimized an integrated approach and stimulates discussion. I assigned individuals to the Planning Groups.

REPORTS FROM THE PLANNING GROUPS

Martha Kostuch, Coordinator

The reporter from each Planning Group will give a five minute presentation. We will proceed in numerical order:

1. Reporter is D. McCoy
2. Reporter is M. Prior
3. Reporter is A. Lopez
4. Reporter is P. Sims
5. Reporter is R. Smith

Report from Planning Group 1

Information Gaps

1. There is a need for information regarding the chemical composition of emissions from sour gas wells, sour gas plants, oil refineries, fertilizer plants, and coal-burning electrical generating plants, as well as other sources of acid forming emissions.
    a. There are knowledge gaps regarding the effects of these emissions on the health of farm animals and humans.

Priorities

1. There is a lack of information on the effects of sour gas and acid forming emissions on the health of farm animals.

   a. Develop a simple diagnostic technique, or at least a definitive test, which indicates whether or not animals have been exposed to sour gas. The diagnostic test should be specific for sour gas or acid forming emissions.

2. There is a need for multidisciplinary epidemiological studies on the effects of acid forming emissions on livestock and crop production.
   a. Develop baseline values in livestock for deficiencies that have been associated with acid forming emissions and sour gas well blowouts.
   b. Recommend that livestock producers keep detailed records, in areas that are producing or receiving acid forming emissions. These records should be made available for long-term scientific studies.
   c. Compare the concentration of trace elements in slaughter house specimens from areas which receive high concentrations of acid forming emissions with specimens from areas which do not receive acid forming emissions.
3. There is a need to document the interactions between changing agricultural practices and the effects of acid forming emissions.
   a. Study the interactions between the use of fertilizers and other agricultural chemicals and the effects of acid forming emissions on the nutritive value of livestock feeds.

b. Evaluate the current nutritional practices of supplementing livestock diets with trace nutrients.

c. Evaluate the interactions among the genetic composition, genetic selection of livestock, trace element supplementation, and acid forming emissions.

Report from Planning Group 2

Information Gaps

1. There should be more communication among the oil and gas industry, the government of Alberta and the livestock producers regarding the issues that have been voiced at the workshop.

    a. The onus is almost exclusively on the livestock producer to prove that sour gas and acid forming emissions have an effect on the health of animals and human beings. The government of Alberta needs to take responsibility for safeguarding environmental health. This is especially applicable to assuring the care of new and innovative technologies in order to reduce the quantity of acid forming emissions being released into the environment.

    b. The economic impact of acid forming emissions on Alberta's agriculture has not been established.

    c. The government should clearly state the priority that research on acid forming emissions and sour gas has or will be given. This is especially important since it generally determines the appropriation of government funds.

2. There is a need for evaluation of current research methods and interpretations of the research and anecdotal information that is currently available on the health effects of sour gas and acid forming emissions.
    a. There is not sufficient baseline data for the parameters currently used to evaluate the effects of sour gas or acid forming emissions in farm animals.
    b. Sample size and observation intervals need to be statistically evaluated. How many cows must be evaluated to accurately estimate the effects of acid forming emissions or sour gas on the population? Is an observation made on a particular farm on a single day valid for the 365-day operation of the farm?
    c. Has a cause and effect relationship been established? Have the emitted substances been identified? Should the onus be on the agricultural industry to prove that sour gas and acid forming emissions are harmful to the health of farm animals and human beings?
    d. Standardize the terminology used to describe emissions and their health effects.

Priorities

1. Develop diagnostic test(s) and research procedures that would indicate the effects of sour gas and acid forming emissions on farm animals.
    a. Establish sentinel herds in emission deposition zones to evaluate the long term effects of acid forming emissions on livestock.
    b. Investigate the use of simple biological monitors.
2. Undertake epidemiological studies to establish average values for selected parameters, and to determine the effects of sour gas and acid forming emissions in the exposed population of farm animals.
3. Improve the flow of information among the Alberta Government, oil and gas industry, and livestock producers to clearly define the problem.
    a. Improve access to the data by establishing a central data repository.
    b. Supply more information to the public on the frequency of sour gas plant upsets and on the chemicals being emitted while the plant operates under upset conditions.
    c. Encourage detailed farm record keeping.

Report from Planning Group 3

Information Gaps

1. There is a lack of documentation on the harmful effects of acid forming emissions on animal health.
2. There is a need to improve the lack of communication between the oil and gas industry, Alberta Government, Energy Resources Conservation Board (ERCB), and the agricultural industry.
3. There is a lack of appropriate environmental legislation regulating the oil and gas industry.

Priorities

1. Develop a coordinated effort to investigate the effects of acid forming emissions on animal and human health.
    a. Assist producers in keeping detailed production records.
    b. Have diagnostic laboratories keep appropriate records relating to a particular geographic area of Alberta.
    c. Prepare and publish epidemiological studies.
    d. Study the existing communications between government, including the ERCB, oil and gas industry, and the agricultural community.
2. Establish a central repository and communications centre for all information relating to the harmful effects of acid forming emissions and sour gas on animal and human health.
    a. Establish a toxicology centre that would serve as a repository and communications focal point for all

information relating to the harmful effects of acid forming emissions on animal and human health, crops, soil and water.

b. Create a medium by which information can be exchanged between government, the oil and gas industry, and the agricultural community.

3. Review the effectiveness of existing legislation pertaining to the regulation of sour gas operations, and to all other industries that are point sources of acid forming emissions.
    a. Improve the monitoring of all emissions in terms of chemical composition and concentration from oil wells, tank batteries, and sour gas operations.
    b. Create an arbitration board to settle disputes that arise between animal owners and the oil and gas industry.

Report from Planning Group 4

Information Gaps

1. The effects of acid forming emissions and sour gas on cattle are not well established.
2. The chemical composition of emissions from sour gas plants under all operating conditions is not known.

Priorities

1. Establish methodologies and protocols for evaluating the effects of acid forming emissions on animal and human health.

   a. Have a workshop on methods to develop protocols for field studies.
   b. Establish methodologies to evaluate livestock feed and animal performance versus the effects of acid forming emissions and sour gas.
   c. Establish procedures to evaluate the economic impact of acid forming emissions on livestock production.

2. Establish a field service team to follow the protocols outlined in Item 1.

Report from Planning Group 5

Information Gaps

1. Procedures for communication among government, farmers, and the oil and gas industry outside of the judicial system have not been developed.
2. Sour gas is not just hydrogen sulfide. Sour gas is a complex chemical mixture of toxic substances and little is known about the toxicology of this substance.
3. The toxicology of substances emitted during upset conditions in a sour gas plant, and substances emitted under emergency situations such as well blowouts is not known.

Priorities

1. Set up a review panel to arbitrate losses that occur from sour gas well blowouts, sour gas plants operating under upset conditions, and acid forming emissions.
    a. The panel should not place the entire burden of proof on the harmed party.
2. Study, epidemiologically, the effects of acid forming and other emissions on farm animals, human beings, crops, dugouts, and soils.
3. Undertake long-term controlled studies on actual emissions from sour gas wells, sour gas plants and other point sources of toxic emissions.
    a. Include animal growth, reproduction, immune system, and nutrition in the studies.
    b. Establish sentinel farms for detailed studies in areas which receive fumes, drifting sulfur, and acid forming emissions.

RESEARCH PLANNING AND PRIORITIES

L.E. Lillie

It is difficult for a single individual to summarize the collective ideas and expertise which contribute to a workshop like this. There is, as expected, a degree of difference in the reports of the various discussion groups, but there is also a degree of commonality. I started the summarization process earlier in the day and made additions as the group reports have been presented. If anyone feels that a particular point of view has not been adequately represented, please feel free to agree with, amplify or oppose any of the points which I emphasize in this summary.

Information and Communications

When complicated problems are being discussed, information and communication almost certainly become major factors with which involved and affected individuals are concerned. When the nature of a problem is such that it tends toward, if not confrontation, at least strong differences of opinion, then information exchange becomes even more important. I believe all of the discussion groups emphasized this point.

The unit of government to which I belong has no statutory responsibility. It is not at this time involved in setting standards, monitoring compliance or enforcing any legislation. Neither is it responsible for providing first line consulting services to livestock producers when they are facing a problem or are involved in a conflict. So, to some extent, I have had the luxury of being able to sit back and observe the interactions between producers, government representatives, and industry, particularly in relation to the sour gas question. One thing that I have observed is that the responsibility for investigating and attempting to resolve either a chronic problem, such as the effects of a gas plant operation, or acute single incident problems such as a blowout, seems to be very diffuse. There are many agencies involved, and many individuals or offices seem to have a piece of the action. In the past, these individuals and offices have often seemed to work in splendid isolation one from another, and according to their specific responsibilities. However, finding out who, if anyone, was actually in charge has not always been an easy task.

This situation is changing, and a more organized response to events, a clearer chain of command, and a pre-planned response is, perhaps, one of the few benefits to arise from the Lodgepole incident, at least with respect to potentially catastrophic events.

The response to perceived problems, however, does not seem to have changed much. And I often wonder how livestock producers must feel by the time the fourth or fifth group of people from the different government agencies have come along to interview them. The situation is probably not much better when producers are trying to get information to enable them to deal with the problem. I have often been contacted by individuals who have already been referred to three or four government agencies, each of which says that his problem, or some part of it, is someone else's responsibility.

All groups, then, have stressed the need for communication, coordination and information, particularly during an environmental incident, but also in dealing with the day to day interactions between producers, government agencies and the petroleum, gas and sulphur industries. While this need is not new to any of us, it is, nonetheless, the first and, perhaps, the most important finding of this workshop.

Availability of Information

Leading directly from the previous finding is the continued need for availability of, and access to, existing relevant information. Many different agencies, groups and individuals have an interest in, or are otherwise involved with, the questions of the impact of acid emissions on the environment, on agriculture in general, and on livestock production in particular, as well as the possible effects on themselves and their families.

Again, there is the sense that a number of different agencies and individuals, including government, industry and universities, are searching the available literature and establishing and maintaining files and data banks on the effects of acid emissions. At the same time, there seems to be little coordination between these different information-gathering activities, potential duplication of effort and little collective understanding of where these different banks and files of information might be, who has them and how they can be accessed.

Somehow or other, we need to establish better coordination of the sources of available information on the subject of the effects of sour gas on livestock and perhaps create a single data bank to which all parties may have access. This information must include data which is presented in a way that is useful to livestock producers, veterinarians and agricultural fieldmen who are on the front line, as well as more formal research data.

Livestock producers have a need for information which is somewhat different from that required by those of us who are involved in basic or applied research, environmental management or commercial resource extraction. Producers are expert generalists who have to know something about a lot of different things in order to stay in business. Many of the rest of us have the luxury of being able to concentrate our information-gathering activities on more specific in-depth areas; and neither the information, nor the lack of it, directly affects us in a personal way. However, for livestock producers, information (or the lack of it) affects how they manage their business and, therefore, their personal livelihood. It is only reasonable then, that requests from livestock producers represent an immediate, keen, financial and personal need.

One of the important things that has been brought out over the course of this meeting is the need to collect and store anecdotal information. Anecdotal information, based on a decreased agricultural productivity, is often the first sign of a potential problem. It is the tip of the proverbial iceberg. This is true whether the problems identified ultimately prove to be related to sour gas or acid emissions, or are actually caused by or associated with something entirely different. It must be both confusing and frustrating for producers to not know where they can get in contact with someone who will try to respond to their questions without a merry-go-round of sequential referrals to other agencies. I know that the Centre frequently gets calls from individuals in this situation. Whenever possible, we try to help these individuals so they don't have to be referred further, but sometimes further referral proves necessary because we just do not have the answer.

Livestock producers need to know where to go and what to do for information without having to go through every governmental department. The Department of Agriculture has been incredibly successful over the years in making information about production methods, economics, farm safety and many other subjects readily available to producers in a variety of formats. Probably because of the different and perhaps unclear division of responsibilities, governments have been less successful in providing information on environmental problems affecting agriculture and the livestock industry.

Can some common point source of information on this increasingly important aspect of livestock production be devised to which livestock producers will have ready access? A need for such a source has been clearly articulated in this workshop.

A Question of Credibility

An important corollary to the provision of information on environmental matters is the credibility of that information. There is clearly a credibility gap between those individuals, particularly within government, whose job it is to provide information on environmental matters and those members of the public, including livestock producers, who are seeking that information. There is a profound reluctance to believe information on environmental matters coming from either governmental or industrial sources, particularly when that information does not support a worst-case scenario. One of the largest, independently conducted studies in the area of gas plant operations, the "Pincher Creek Study", seems to suffer from a lack of credibility. Whether this is due to flaws in the study or to the natural reluctance of people to accept results which conflict with their existing views is not something we will resolve here. However, it does reflect a kind of malaise of mutual distrust in our society which is unlikely to be resolved in the near future and which could well affect any further studies undertaken on the effects of sour gas. There is also some degree of reluctance by government and industry to use anecdotal information generated by livestock producers.

The Need for Independent Arbitration

When a conflict arises between a commercial company and a livestock producer, the producer often feels that the deck is stacked against him or her. The burden of proof always seems to be on the producer. This is true of a perceived problem, suspected for a long time, or some catastrophic event for which the long term effects are uncertain.

Producers see a mass of resources and high-priced help available to resource companies. Unfortunately, the producers often perceive that all of the myriad agencies and resources of government are also aligned with these companies. This perception, whether valid or not, is widespread and generates the need for some type of advocate or independent arbitration board to which livestock producers can present their concerns. Whether this function could be adequately served by the existing Farmers Advocate's Office or whether a new agency needs to be established is unclear. In either case, livestock producers would like to feel that, in their dealings with resource companies and government agencies, they are dealing on a more level playing field.

Field Investigations of Acid Gas-Related Problems in Livestock

Quite a bit of discussion revolved around how perceived problems involving livestock, livestock producers and the sour gas industry should be tackled. For convenience, I have divided these into field and laboratory investigations. I will tackle the field investigations first.

A major concern related to an on-farm investigation of possible acid gas-related problems is again one of the integration and coordination of the activities of different individuals and agencies. Who is really in charge? To how many different individuals and agencies does the producer have to tell his story? Who will decide what animals to examine, what samples to take for analysis, where to send those samples, and what parameters should be determined? More importantly, who will collate all of the different pieces of information into some kind of collective report that will be useful in trying the resolve the issue?

The most important individuals are those who are in the immediate area; namely the livestock producer, the local veterinarian and the local agrologist. All of the investigations by highly trained investigators must revolve around these three people. These are the individuals who must deal with the problem on a day-to-day basis, whether the problem ultimately proves to be related, wholly or partially, to sour gas exposure or whether it proves to be unrelated to sour gas.

It is of paramount importance that a thorough investigation of the on-farm situation be carried out as soon as possible after a particular event has occurred or when a problem is first suspected. This investigation should, if at all possible, integrate and coordinate the needs of different agencies that might have to consider and make a judgment as to whether a problem is acid gas related.

Coordination and Standardization of Investigations

It is essential that on-farm problems be investigated in a thorough, consistent and generally acceptable manner by an investigative team which has the broad spectrum expertise needed to look at problems of nutrition, reproduction, clinical disease, herd records, toxicology, and all of the other related factors. It is of equal importance that this investigative team have access to the laboratory services which will be needed in order to support and validate the on-farm investigation.

The most important factor about an on-farm investigation is that it should not be done on an ad hoc basis by individual(s) who have not been adequately prepared in advance. This means that the investigation needs to be carried out according to a plan which has been carefully prepared in advance. It does not mean that this plan should be so rigid that it cannot be modified to specific conditions on a specific premises at a specific time. It does mean that the investigation must proceed in an orderly, sequential way so that nothing of critical importance is missed. Attention must not be diverted to what might be the most apparent but perhaps the least important feature.

I know that considerable efforts have already been expended to create such a standard plan or protocol for the field investigation of acid gas related problems and that the technical capability to conduct a successful investigation does exist. I am less certain that the jurisdictional problems associated with a multi-agency investigation have been fully resolved.

Any investigative team which does not have access to a set of reasonably complete and consistently maintained farm records stretching back over a period of some years, will have great difficulty conducting a successful investigation. There is no substitute for adequate records and any producer who claims to have a problem but who does not have adequate records is almost certain to be disappointed with the results of an investigation.

An on-farm investigation team will need to look at a large number of factors. Of course, if the animals have been exposed to a full-fledged blowout for some period of time, the job may be more straight-forward. Sudden deaths and evidence of an obvious clinical disease of sudden onset associated with a blowout situation may provide a relatively clear-cut cause and effect relationship. However, most of the biological effects with which we are concerned are not nearly so obvious. And determining these effects can be hampered because the biomarkers have not all been well established.

The science of toxicology assumes that the responses or severity of the biological effects are related to exposure. Parameters of exposure are based on the amount of the poison taken into the body, or a best estimate of the amount. Exposure parameters include the poison concentration, duration or the time interval, the amount taken into the body, and the frequency of availability. In actual field exposures, all of the parameters in the exposure paradigm can be highly variable. Erratic exposure is often coupled with other, often subtle, factors such as sub-clinical nutritional or infectious diseases. Separating these intercurrent factors from the effects of acid gas exposure may be difficult, sometimes impossible, no matter how thorough the investigation. In these circumstances, the investigative team will need to look at many factors relating to epidemiology and health of the herd, including herd management, reproductive performance, nutrition, air, water, soil and forage quality, intercurrent disease, and climatic factors.

Many contributors to the workshop spoke about how an investigative team can be created to conduct a thorough on-farm investigation of complex and difficult production problems. The answer is not some kind of acid gas "SWAT" team. Rather, the key is to have an organized, coordinated and well-planned approach by a team of highly trained professionals. This means that the question of who is to be involved, how they are to function, and who is to direct the investigation needs to be discussed and agreed upon well in advance.

And last but not least, the difficult question of who or what agency is to provide the necessary resources must be addressed. The availability of expertly trained professional and technical staff, as well as the availability of the financial resources for the necessary field and laboratory work must be available when needed and not be left to resolve when the call is received. The cost of the necessary laboratory studies, in particular, is always underestimated. Samples do not just get sent off to "the lab". Laboratories are expensive to establish and operate and almost always have more work than they can reasonably handle. Adequate quality control of laboratory operations must be in place so that when samples are received, there can be some confidence in the validity of the results. And a reasonable priority must be established for material derived from field investigations so that the team can complete their reports in a timely manner. Blind faith and good intentions will not get the job done; tight organization and adequate resources will.

Characterization of Emissions

If we are to relate perceived disease problems in livestock to emissions of acid gases, then we must know the character of those emissions, their quantity, their source, their destination and what happens to them between the time they are emitted and the time they come into contact with susceptible livestock. Much work has and is being done to categorize at least some of the sources of emissions, as well as the nature and quantity of those emissions. The point has been made frequently at this workshop that it is necessary to know what is coming out of a stack or other point source during both normal and abnormal operating conditions. It is necessary to know the chemical species of the emissions, the potential toxicity of the different chemical species, and the relative susceptibility of livestock or other potential target groups.

The toxicity of emissions is a function of the intrinsic chemical properties of the gas and of the dose which is received. The dose, in turn, is comprised of the concentration of the gas(es) to which the animals are exposed and the length of time to which they are exposed. In order to prove that a disease condition is due to an emitted gas, it is necessary to show that the affected animals were really exposed to a strong enough concentration for a long enough period of time. This is usually the most difficult piece of information to obtain. Finally, many factors can affect both the chemical characteristics of emissions and their concentration between the time they are emitted and the time they contact some potentially susceptible species. These factors may include topography, wind speed and direction, temperature and precipitation, as well as a complex sequence of chemical reactions which many gases undergo when they are emitted into the atmosphere.

Improved Emission Control Technology

The simplest way, in theory at least, to prevent industrial emissions or effluents from affecting either human or animal populations is to prevent or minimize their release into the environment. In the pre-environmental awareness age, chemical waste products of just about every imaginable kind were simply allowed to escape up a smoke stack, were allowed to pour out of a drain pipe, or they were simply dumped on the surface of the land or into crudely constructed landfills. In general, environmental toxicologists agree that there is some temporal summation in terms of biological effects. Much has been accomplished by industry in the last decade to improve the handling of waste products, but much more remains to be done. And it must be done in the context of economic reality. Economic reality, in turn, can no longer be used by industry as a reason to do nothing. Conversely, neither can economic reality be ignored by environmental advocacy groups. We all share the same planet and we will need to go on sharing that planet for some indefinable period into the future.

In the context of acid emissions, efforts needs to continue to be made directly by industry and indirectly by both government and industry to continue to reduce acidic emissions. This pertains particularly to emissions that occur during periods of processing upsets in the processing plant. It is arguable whether, in the interests of economic production, an industry has the moral right to negatively affect their neighbours. Certain societal pressures are likely to continue on industrial operations in an effort to improve waste management technology, whether this is removal, recycling, or rendering wastes into some inert form.

In any event, pressure is likely to continue on the sour gas industry to progressively minimize acid gas emissions. The technology for considerable reduction of acidic emissions appears to be available. It is not always agreed upon as to whether that technology is "economic" or not. But it is necessary in determining whether emission control technology is economic to consider not only the economics of the industry itself, but also of other industries sharing the same space at the same time. This is simply being a good neighbour. At the same time, those on the opposite side of the barbed wire fence need to ensure that complaints against the industry are well-founded and that the industry is not blamed for problems in livestock production which could be there whether or not the industry was located nearby.

Laboratory Investigations

We have not yet discussed the role of research, both basic and applied, in confirming the effects of exposure to acid gases and the ways of overcoming the possible effects of such exposures. Research laboratories attempt to duplicate conditions which occur in real life, but in very controlled situations. They seek to eliminate the effects of extraneous or secondary factors.

When animals are exposed to irritating gases, the most obvious effects are observed in the eyes and nose. Animals may also be affected indirectly by possible effects of the chemicals on food stuffs which the animals may consume. In the case of acid forming gases, this would be considered an indirect effect. Indirect effects usually occur over a long period of time and may be so subtle that it is hard to delineate the effect. Indirect effects may also be confused with a wide range of other factors which may impair productivity. In all probability, the animals are exposed through the respiratory tract and the inhaled substances may affect a wide variety of body systems, depending on the chemical nature of the substances.

Research on the effects of acid gases may take many forms. Some of this consists of surveys of the measurement of the chemical constitution of soil, water or air. Some of it may take the form of basic studies of the effects of acid forming gases on various biological models, for example, isolated nerve cells or isolated cellular organelles such as mitochondria. Other studies may include the exposure of whole animals to known concentrations of gases under highly controlled conditions for specified periods of time.

Research is expensive and there are many claims for each research dollar. Interest groups seek to lobby both government and industry to support research in their particular area of interest, from basic sciences to medical research to aerospace engineering and everything in between. It is an axiom that there is always more worthwhile research that needs to be done than there is money to support that research. That means, inevitably, that choices have to be made and that some groups will be disappointed. This workshop has clearly pointed out that research on the health effects of acid forming gases is a problem which is of particular importance in the province of Alberta. And interested groups, whether industry, agricultural producers or environmental advocacy groups, will need to continue to make their case known to those that have the responsibility of assigning research funds.

It is not enough just to say that "more research should be done" or that "more money should be spent on research". It is necessary to put forth a continued, lucid and rational case for further research on the effects of acid emissions. Individuals and groups which are part of, or which feel they may be affected by the acid gas industry, must continue to make their case. This workshop has identified the need for more definitive biological markers of the effects of acid forming emissions on domesticated animals.

Long Term vs. Short Term Effects

In the preceding discussion, mention was made of long term vs. short term effects and direct vs. indirect effects. Because animals don't drop dead or become overtly sick, that does not mean that there is no problem. Livestock are units of production and many factors can contribute to sub-optimal production. Some of these factors may be associated with a clinically apparent disease and some may not. Some diseases or effects may become apparent at or near the time of alleged exposure to a noxious substance and some may not become apparent for a long time thereafter. Indirect effects such as changes in the availability of essential nutrients, for example, essential trace elements, may not become apparent for a long period of time, and even then, may become apparent in a very subtle and almost subclinical way. More importantly, livestock are units of production which are supposed to reproduce themselves. If the reproductive potential of a herd or a flock is reduced by even a small percent, that reduction may affect very directly the profitability of the operation.

Unfortunately, it is the subtle, subclinical indirect effects or marginal effects on reproductive potential which are by far the most difficult to demonstrate. Distinguishing between the contribution that may be associated with the operation of an adjacent gas processing plant and any coincidental factors which have nothing to do with gas plant operations can be difficult, expensive, drawn-out, and, ultimately, may be impossible to delineate. Many of these conditions occur in areas of the country and in areas of the world far removed from any natural gas industry. This neither proves nor disproves the contribution of adjacent gas plant operations. It only makes determining their contribution more difficult.

Summary

This workshop has focussed on the effects of acid forming emissions on livestock. It has enabled livestock producers, industrial representatives and representatives from the departments of Agriculture and Environment to come together to discuss a matter of mutual concern. These discussions have focussed on a number of specific areas including:

(1) information and communication availability and exchange;
(2) the need for some kind of arbitration process;
(3) the investigation of livestock problems which may be associated with sour gas plant operations;
(4) the characterization of gas plant emissions;
(5) the needs for continued research and development of more definitive biomarkers.

These problems are not going to be easily resolved, but will require a continued effort by the natural gas industry, the livestock industry, and the various responsible government agencies, particularly the Departments of Agriculture, Energy and Natural Resources, Energy Resources Conservation Board, and Environment. We will have to continue to attempt to identify, resolve and ultimately prevent conflicts between two important industries which share the same space and which make important contributions to the Alberta economy.

CONCLUDING REMARKS

R. Christian

I have the honour of concluding the workshop. The first thing that I wish to do in conclusion, however, is to acknowledge the work and efforts of Dr. Coppock, Dr. Beck, Dr. Church, and Dr. Kostuch in organizing this workshop. I would like to give them a round of applause.

Yesterday morning we reviewed the purpose, and I think that we have accomplished the three objectives that were identified in the purpose statement. This is a super accomplishment.

We had a lot of information presented as a result of experiences in the field. The veterinary diagnostic laboratories find that very useful. But the exchange of information is a two-way street. Some producers who have observed problems in the field can now better understand what information there is from the scientific community.

When the Lodgepole blowout occurred, we were in a position of extrapolating from what the scientific literature said occurred after H_2S exposure, without really having a reasonable knowledge of the other possibilities that can occur in the field. Certainly the H_2S component of sour gas does not explain all of the problems which occurred in the field. The Lodgepole observations have given us some good direction. For example, the information about pigs and their reaction suggests that perhaps pigs would be a very good species to study for the reproductive effects of sour gas.

I think that we now better realize the complexity of these situations. We know that a very intensive review of management, nutrition and other diseases must be part of the field investigating activity, for example. In this workshop, a good review was presented of the scientific and other data in the literature. And we heard about sources for research funding.

Dr. Sims and Dr. Lillie made a couple of points at the end of the workshop regarding the acid deposition research program. Certainly, funding is going to be limited, but I think that progress will be made even though it may seem slow. Acid deposition is a big, tough problem. As Dr. Lillie pointed out, the priority of this research in terms of funding is always a question.

Thank you all for coming. We had a good representation from the agriculture industry, energy industry, university researchers, and from government. Thank you very much.

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